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RESTRICTED.

MILITARY OPERATIONAL RESEARCH REPORT

No. 61.

STUDY No. 11

ISSUED BY MOTION STUDY WING

MOTION STUDIES OF GERMAN TANKS.

DECEMBER 1947.

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ACKNOWLEDGEMENTS.

We wish to record our appreciation of the technical assistance and facilities offered us during the study of the vehicles by the P.V. Wing of the Military College of Science and P.V.D.D., Ministry of Supply.

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Prepared by: Capt. C. Tunnicliffe, Gen. List.

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ABSTRACT

This Report describes the Motion Studies undertaken on the German Tiger, Royal Tiger, and Panther Tanks. The objects of the Studies were first to examine the main armament loading arrangements and assess the loading times, and secondly to examine the crew's controls and accommodation.

(The report is not intended to give a technical assessment of the vehicle. Technical data is given only where it is necessary for simplification or clarification of description.)

Our detailed conclusions are made in Section 5 of this report. Mainly they are as follows:-

(a) Little consideration has been given, in the design of these vehicles, for the comfort of the gunner, and most of the crew's controls are so positioned as to be operated only with discomfort and fatigue. A short study of each vehicle's mock-up by a physiologist would have revealed most of these undesirable qualities.

(b) The gunner and bow-gunner should have adequate vision facilities; in all three tanks this is not possible with the equipment provided.

(c) The ammunition bin fittings are badly designed in all three tanks; hence, loading times are high, and the loaders are more prone to injury than they would be when loading from well-planned bins.

DECEMBER 1947.

SECTION 1.

INTRODUCTION AND METHOD OF STUDY.

This series of studies was undertaken at the F.V. Wing, M.C.S., and at F.V.D.D., with the objects of firstly, inspecting the main armament loading arrangements and comparing them with those of British tanks, and secondly, examining the crew's position and seating from a physiological viewpoint and to assess how they would affect operation of the various controls and devices of each crew member.

The report is divided into four main parts. The first three of these deal with the detailed description of each of the three tanks. The last part is in the form of a summary of the first three, and compares the features of each tank with the others', and with those of British tanks. It is hoped that this part of the report will give a clear picture of the good and bad features of the three German tanks to British designers.

The study of each vehicle was set out as follows:-

- (a) The controls and seating were tested for "usability".
- (b) The main armament ammunition stowage was inspected, and it was determined from which racks/bins rounds would be loaded in action.
- (c) The loaders were instructed in the best method of loading from these racks/bins, and were then practiced in the drills before time trials began.
- (d) A series of loading trials was then carried out and the loading times timed with a stopwatch.
- (e) A further series of loading trials was conducted, and the loading was filmed with cine-cameras, which recorded the loading movements for subsequent detailed analysis.
- (f) Any details of exceptional interest in the vehicles were filmed, using both cine and still cameras, for record purposes.

SECTION 2.

MOTION STUDY OF THE "TIGER", MODEL 'H'.

SECTION 2.

MOTION STUDY OF

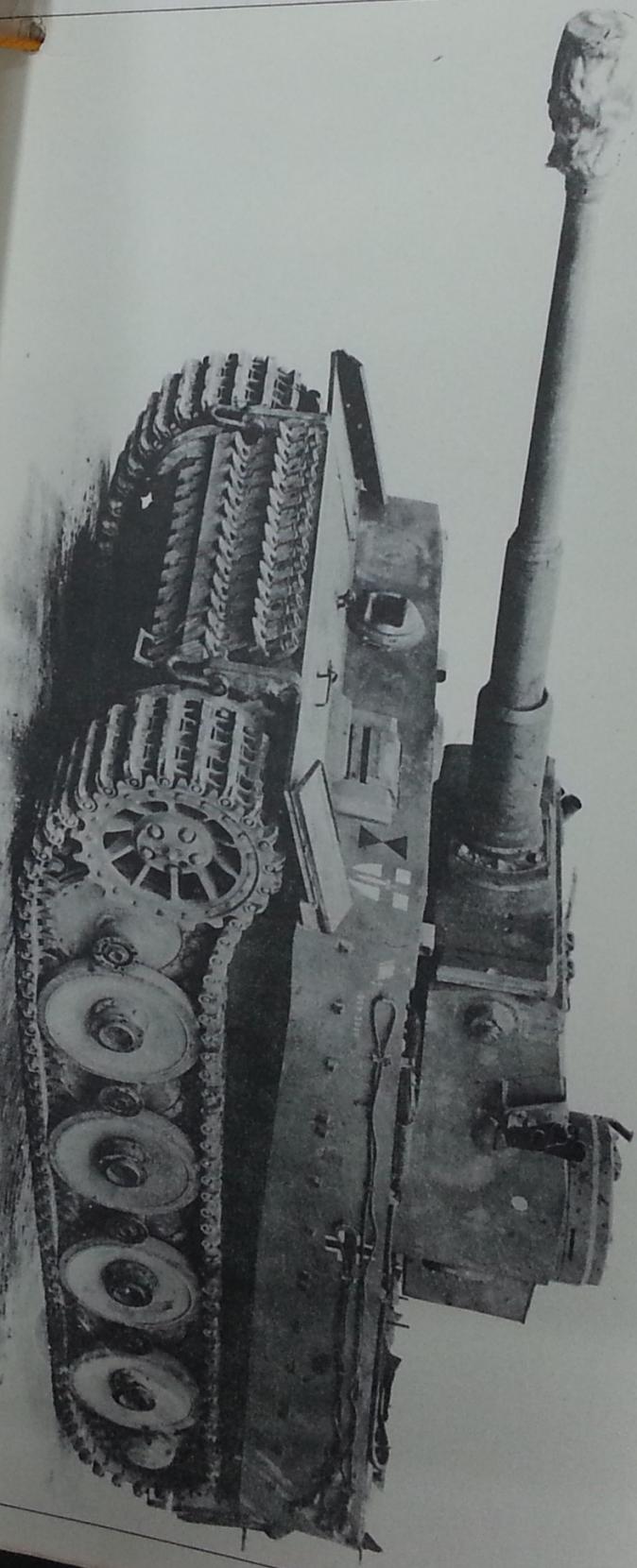
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(THE "TIGER", MODEL 'H').

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The normal drill when using hand traverse would be for the gunner to elevate the gun with his right hand and traverse it with his left hand. In doing so, his left wrist is liable to chafe against the turret ring casing. If he uses his right hand for traversing, he is liable to scrape the back of it on the sharp edge of the clinometer.

The hydraulic power traverse system is controlled by a rocking footplate on the floor in front of the gunner's seat. (See Photo 2). The footplate is pivoted along its transverse axis. In the neutral position, the plate is tilted lower at the front than at the back. On left traverse, the heel end of the plate is depressed until the plate is horizontal. On right traverse, the toe end of the plate is depressed to an angle of 24° from the horizontal.

Since the transverse pivot of the plate is only 8" forward of the front of the gunner's seat, its operation is both awkward and fatiguing. The investigator's boots allowed him barely sufficient ankle flexibility to operate the pedal, and quick yet accurate control of the turret's traverse was almost impossible. In addition, when the operator removed his boot from the pedal, the latter did not usually return to neutral and the turret continued to traverse independently. Another weak feature was that, when the gun was elevated, the gunner's movements inadvertently tilted the footplate and traversed the turret. The design and position of the footplate are poor; accurate control of the turret on traverse is almost impossible, and the strain of operating the plate is very fatiguing.

The main armament is fired electrically by a curved steel bar pivoted on to the shaft of the elevating wheel. The bar can be operated by one finger but the gunner must first of all release the wheel handles, unless the latter is at top centre of its arc of operation.

The MC firing pedal is operated by the gunner's right foot. The gunner can easily reach it, but in doing so, and in actually operating the pedal, he is liable inadvertently to tilt the power traverse footplate.

(c) Sighting and Vision. The gun sight is a binocular telescope, type T.Z.F. 9 (b). (See Photo 3.) The browpad is well-shaped, but the rubber is too hard for comfort. It interferes with the gunner's headset when he is sighting.

The clinometer is mounted on the right side of the sight and is positive in action. It is convenient to use, but the lower end is sharp and projecting and is liable to catch the gunner's right hand.

The only other vision device for the gunner is a glass-covered vision slit, 5" wide and 3" high, let into the turret wall at 11 o'clock and facing half-left. A block facing forward would have been more useful, since the gunner might have used it when looking for targets over a wider angle than that afforded by the sighting telescope.

(d) Conclusion. In general, the gunner's position is very bad. It is very cramped, the gun controls are badly designed and positioned, and the vision facilities are inadequate.

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The only other vision device for the gunner is a glass-covered vision slit, 5" wide and $\frac{3}{8}$ " high, let into the turret wall at 11 o'clock and facing half-left. A block facing forward would have been more useful, since the gunner might have used it when looking for targets over a wider angle than that afforded by the sighting telescope.

(d) Conclusion. In general, the gunner's position is very bad. It is very cramped, the gun controls are badly designed and positioned, and the vision facilities are inadequate.

THE LOADER

(a) Seat and Position. The loader's station is on the right side of the main armament. A padded seat and backrest are provided, and the loader sits facing rear in relative comfort. The seat is not adjustable, but can be lifted and swung sideways under the gun when not required. (See Photo 4).

The loader's station is roomy and there are few obstructions to loading. Both factors are important when handling the large ammunition used in the Tank.

(b) Coaxial MG 34. The loader has great difficulty in loading the coaxial MG because it is mounted so near to the main armament. This position is a very bad feature, since, as the MG cannot be reloaded quickly, belts can only be fired intermittently and targets appearing for only a few seconds are likely to be missed during reloading.

(c) Vision. The loader's sole vision device is a glass-covered vision slit similar to the gunner's. It is situated in the turret wall at 2 o'clock and faces half-right. This is desirable since it covers a field of view not covered by the commander's set of slits in the cupola.

(d) Conclusion. Apart from the difficulty of loading the MG, the loader's position is satisfactory.

THE DRIVER

(a) Seat and Position. The driver sits in the front left corner of the hull. The seat is padded and is adjustable for forward-backward movement. (See Photo 5.) The backrest is padded and hinged to the seat. Its angle of tilt is adjustable and the backrest can be dropped back flat to allow the driver easy access to the turret. The driver's legs are hemmed in uncomfortably between the steering band casings.

Since the height of the seat is non-adjustable, the driver has no "opened-up" position.

(b) Driving Controls. No detailed study was made of the driving controls, but their design and position are similar to the lower set of controls in the Royal Tiger. These are described in detail in the Report on that Tank.

(c) Vision. The driver's main vision device is a visor, protected by a laminated glass block approx. 10" wide and 3" high, and mounted in the hull front plate. The block can be partly or wholly obscured by an exterior sliding shutter which is adjusted by a handwheel on the mounting. The angle of view is satisfactory only when the shutter is fully open.

In addition to the glass block, an episcopic 5" wide is mounted in the driver's roof hatch door and faces half-left.

(d) Conclusion. Although the driver's position is otherwise reasonably comfortable, his leg-space is inadequate and the absence of an "opened-up" position is a further disadvantage. Driving is simplified by the automatic gearbox. (See Report on Royal Tiger).

MOTION STUDY OF THE TIGER, 'H'

1. INTRODUCTION.

Ammunition stowage and loading have been the major interest in the study of this vehicle, since the crew's positions and controls are described in detail in the omnibus report of the Tiger issued by the School of Tank Technology.

We recommend that the S.T.T. Report be read in conjunction with this report.

2. DESCRIPTION OF THE VEHICLE

The Tiger is a heavy tank weighing 56 tons in battle order. Its armament comprises an 8.8 cm. Kw.K 36 gun mounted coaxially with a 7.92 mm MG 34 in the turret. Another MG 34 is mounted as a bow gun in the hull front vertical plate.

The vehicle is 20' 8 $\frac{1}{2}$ " long (excluding the gun), 12' 3" wide and 9' 5" high. The five members of the crew are the commander, gunner and loader in the turret, and the driver and bow-gunner in the hull front.

3. THE COMMANDER.

(a) Seat and Position. The commander has three alternative positions - sitting on the upper seat, sitting on the lower seat, or standing on the turntable. He would use the first position when the vehicle was not in action and he could keep his roof hatch open; he would use the other two positions when the vehicle was in action and "closed-down".

Although the upper seat is comfortable in itself, the upper position is cramped because the shield, which protects the commander from the movement of the gun, presses against his right side and presses him against the turret wall.

No backrest is provided. The commander's back presses uncomfortably hard against his steel respirator case which is usually stowed behind him. His discomfort would increase when the vehicle was moving.

When sitting on the lower seat, the commander is again pressed in by the gun shield and his left leg chafes against the traverse gearbox. The upper seat drops to form a backrest (see Photo 1), and the position is more comfortable than the upper one.

When standing on the turntable and the vehicle is moving, the commander could be thrown against the seats to his rear and the traverse gearbox to his left front. He is also hammed in between the gearbox and the gun.

(b) Controls and Vision. The commander can traverse the turret by means of a small handwheel mounted on the left. (see Photo 1.) (It can be operated only in conjunction with the gunner's handwheel, since a latch on the latter locks both controls until released by the gunner). The commander's handwheel is badly positioned and awkward to operate, since the left wrist must be twisted to grasp the handle which cannot be gripped by the whole hand. In addition, the wrist chafes against the cupola locking control rod when the wheel is operated from the upper position.

The commander's vision equipment is described in detail in the S.T.T. Report. It comprises five glass-covered vision slits in the cupola and a scissors telescope on an adjustable mounting on the inside of the turret roof. The vision slits do not cover the entire 360° field round the tank and the two rearmost slits are awkward to look through when seated.

No scissors telescope was fitted in the vehicle inspected. The telescope would be used primarily for observation of fire and the commander would be able to observe without exposing his head outside the turret.

(c) Conclusion. The commander's traverse handwheel is basically sound but badly positioned; the vision equipment is reasonable but not fully adequate; and, principally, his positions are cramped and uncomfortable.

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THE GUNNER

(a) Seat and Position. The gunner sits in front of the commander on the left side of the main armament. His seat is elliptically-shaped and padded. It is mounted on a horizontal arm and is not adjustable. (See Photo 2.) The back rest is also padded, and curved to fit the gunner's back.

Although the seat and backrest are comfortable, the position is very cramped. The gunner's feet rest, with toes pointing downwards, on the power traverse footplate, which is centred only 8" in front of, and 12" below, the seat. The gunner's knees are consequently sharply bent, forced half-right by the legshield on his left, and confined between the shield and the elevating handwheel.

In addition, when the gunner leans forward, his body is further twisted; operation of the elevating wheel also increases his discomfort, because he must move his legs further over to the left to reach and operate the controls.

(b) Gun Controls. The elevating handwheel is mounted on a horizontal shaft passing transversely under the gun. (See Photo 2). It is 9" in diameter and situated on the right of the gunner, who would normally operate it with his right hand. The handle on the wheel is too short to be gripped by the whole hand, and the resultant lack of purchase impedes its operation.

The traversing handwheel is 10 $\frac{1}{2}$ " in diameter and is situated in front of, and above the level of, the gunner's seat. (See Photo 3). The wheel is mounted horizontally with the handle on the underside. A plunger-type latch is pivoted to the handle and must be released before either the gunner or the commander can use their respective handwheels.

The gunner's handwheel was remarkably easy to operate, but the reduction of two turns per degree of traverse is so high that traversing through an arc of about 30° or more is slow and tedious.

The gunner's wheel is geared to the commander's and rotates more quickly than it. If the commander traverses rapidly, the gunner's handwheel rotates so rapidly that the gunner is liable to lose control and take his hand from the handle. The latch on the handle will then automatically lock both the traverse handwheels.

7 THE BOW-GUNNER

(a) Seat and Position. The bow-gunner's position is in the front right corner of the hull. His seat is similar to the driver's, but the backrest is smaller and less comfortable. The bow-gunner's knees are cramped in the confined space between the steering band casings, but the position is otherwise spacious and comfortable.

(b) The Bow-Gun. The MG 34 bow gun is housed in a ball-mounting in the front vertical plate. It is controlled by a pistol grip and a headpan on the mounting. (See Photo 6). Since the gun is breech-heavy, a compensating spring is fitted to balance it. However, in the vehicle inspected, the gun and mounting are still unbalanced and the headpan pressed down heavily on the bow-gunner's head, causing acute discomfort.

The bow-gunner also operates the wireless set in the vehicle; this is conveniently situated on the gearbox to his left, where it is easily accessible.

(c) Sighting and Vision. The MG is sighted by a standard episcope telescope (type K.Z.F.2) fitted with a soft, shaped browpad. This is satisfactory. The only other vision device is a 5" wide episcope mounted in the roof hatch and facing half-right. If it had been mounted facing forward, it would have given the bow-gunner a much wider angle of vision. In addition he could have looked for targets without moving the unwieldy gun.

(d) Conclusion. Although his seat is comfortable and his position otherwise spacious, the bow-gunner must sit with his knees in a cramped position, and, when he uses the bow-gun, the headpan presses heavily on his head and causes acute discomfort.

8 LIGHTING.

Festoon lamps are fitted.

- (a) on the turret roof in front of the commander's cupola,
- (b) on the turret roof above the gunner's position,
- (c) on the turret roof above the loader's seat,
- (d) on the driver's instrument panel,
- (e) on the wireless set.

This lighting arrangement is reasonable, but when the vehicle is operating in semi-darkness or in overcast weather, the loader will not be able to see the ammunition in the pannier racks. A festoon lamp in the two panniers on the right side of the hull would have provided reasonable illumination.

9 CREW ACCESS

(a) Hatches. The driver's and bow-gunner's hatches are identical. Both are circular and open sideways with spring assistance. The hatches allow good access to each position but the doors, when open foul the turret on traverse. The doors cannot be closed from inside the vehicle without exposing the crew member's arms.

The commander's fixed cupola is circular and the door is hinged on the right side and opens with spring-assistance. The open door does not fall back flat but stays almost perpendicular and therefore increases the overall height of the tank. The fitting of the set of vision slits for the commander necessitates a deep cupola which restricts his access to and from the turret. The cupola is also used by the gunner, who has no roof hatch of his own.

The loader's hatch is rectangular and the door is hinged at the front. The system for providing spring-assisted opening comprises a spring piston and an arm, mounted on the inside of the turret roof. This occupies valuable headroom, and an orthodox coil spring (as fitted to the cupola door) would have been more satisfactory. The door falls flat on the turret roof when opened and does not increase the height of the tank. The loader must expose himself when closing it from inside the turret.

An escape hatch is provided in the right rear quarter of the turret wall. (See Photo 7). It is circular and the door is hinged at the bottom and drops outwards. Neither opening nor closing is spring-assisted, and once the door is opened, it is too heavy to be closed from inside the turret. In addition, when the door is open, it fouls the hull as the turret is being traversed. Since the loader would not leave the turret when the tank was in action, it appears that the hatch is used solely for escape in emergency, and that empty cases would be flung through the loader's roof hatch.

(b) Conclusion. None of the access hatches is completely satisfactory.

(c) "Baling-Out". The loader's who took part in the trial were timed leaving the various crew stations, opening their hatches and getting outside the vehicle as quickly as possible. They took the following times:-

Commander 9 secs., gunner 12 secs., loader 7.2 secs.,
driver 7 secs., bow-gunner 7 secs.

The gunner "baled-out" through the commander's cupola.

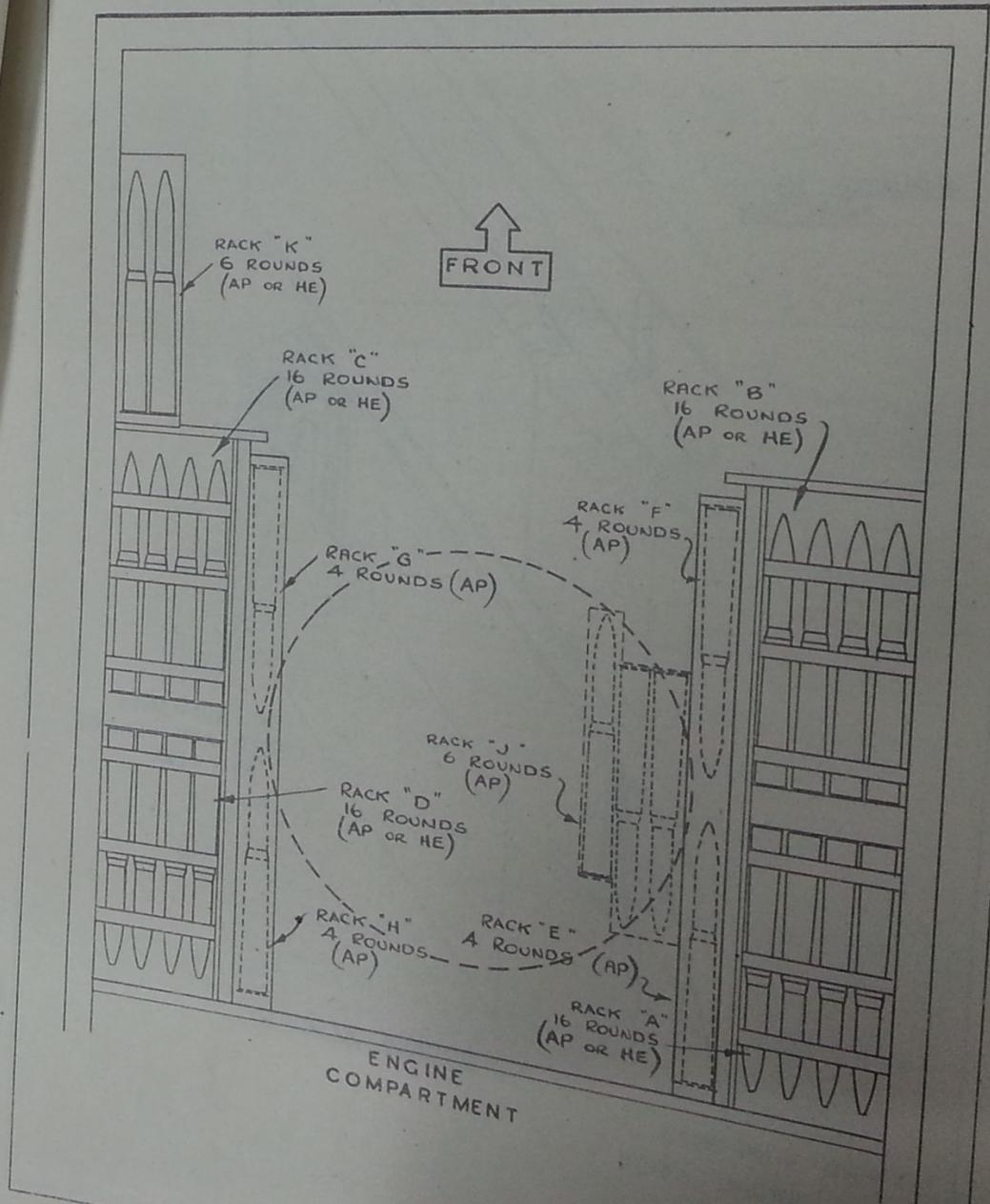
MAIN ARMAMENT LOADING TRIALS

(a) Details of Stowage. A total of 92 rounds of fixed ammunition is stowed in the Tiger, in ten bins arranged as shown in Fig.1.

Bin A in right rear pannier holds	16 rds. AP or HE.
Bin B in right forward pannier holds	16 rds. AP or HE.
Bin C in left forward pannier holds	16 rds. AP or HE.
Bin D in left rear pannier holds	16 rds. AP or HE.
Bin E under right rear hull floor holds	4 rds. AP.
Bin F under right forward hull floor holds	4 rds. AP.
Bin G under left forward hull floor holds	4 rds. AP.
Bin H under left rear hull floor holds	4 rds. AP.
Bin J under turntable holds	6 rds. AP.
Bin K in driver's pannier holds	6 rds. AP.

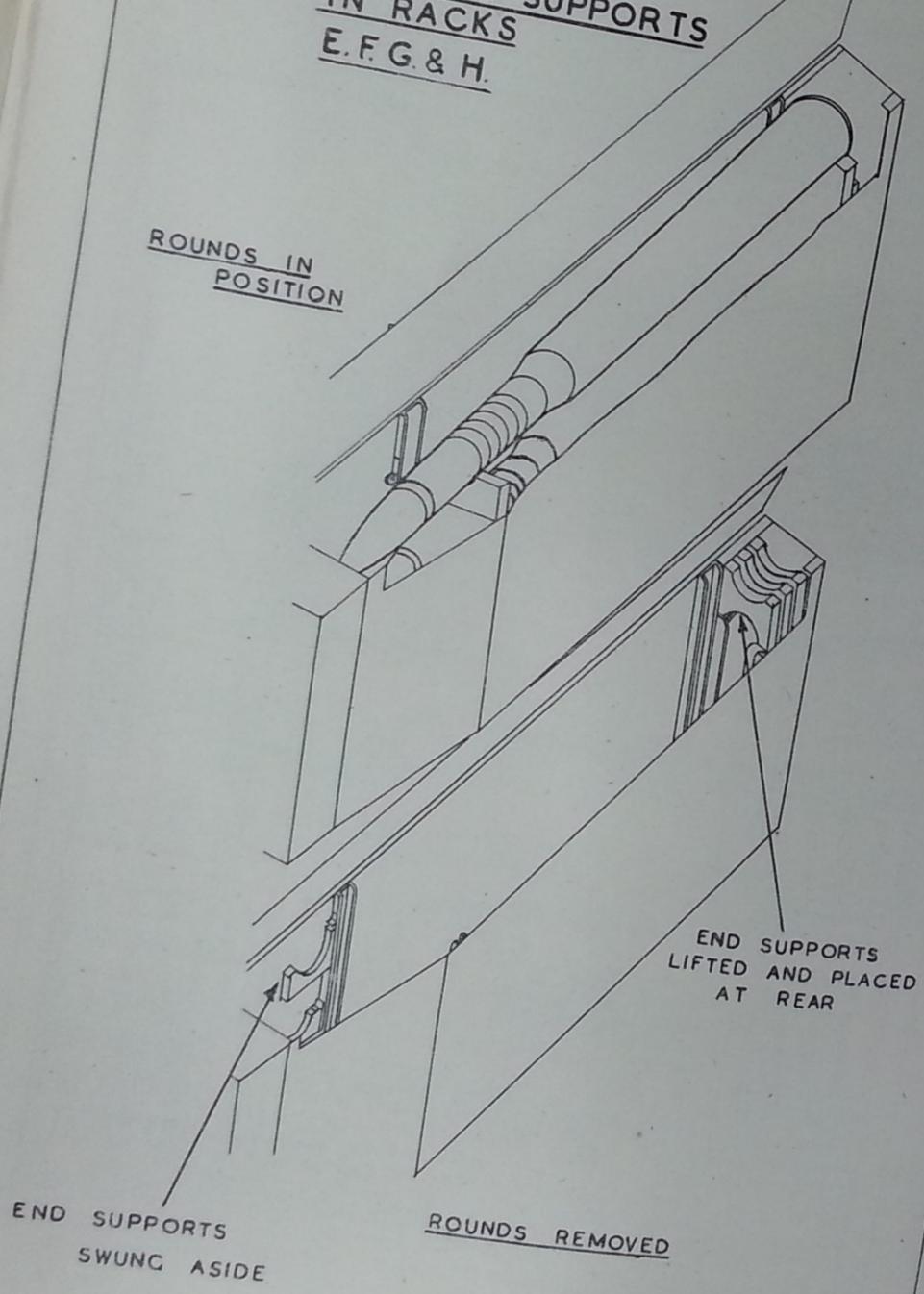
FIGURE . 1.

- TIGER -
PLAN OF AMMUNITION STOWAGE



- TIGER -
PLAN OF END SUPPORTS
IN RACKS
E.F.G. & H.

FIG. 2.



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No ammunition is carried in the turret. All rounds are stowed horizontally in sheet metal bins with folding doors. (See Photo 8).

Except for Bins J and K, the bins are arranged symmetrically on each side of the hull centre line. It was therefore necessary to study only one side of the vehicle, and the results obtained apply equally to the other side with the turret traversed through 180°. For example, comments and loading times for Bin B at 11 o'clock apply equally to Bin D at 5 o'clock.

Table 1 shows the availability of the bins at various turret positions. Rounds from Bin A can be obtained in an arc between 11 and 12 o'clock, from Bin B between 8 and 12 o'clock and from Bin D between 2 and 6 o'clock. The lower three layers of Bin C are available at 8 o'clock and the whole bin between 5 and 7 o'clock.

Table 1.

Turret Position	BIN							Total		
	A	B	C	D	E	F	G	H	J	
12 o'clock	16	16			4	4			6	
1	16				4					46
2	16			16	4					20
3				16	4					36
4				16			4			20
5				16			4			20
6			16	16			4	4		20
7			16	16			4	4		40
8			16				4	4		40
9		16	12				4			20
10		16			4					32
11	16	16			4	4				20
										40

There are never less than 20 rounds available to the loader, in any turret position.

Two fully-experienced loaders took part in the trial:-

Loader A - Gunner Cumpston, height 5' 11" and

Loader B - Trooper Egan, Height 5' 4".

Details of loading trials and times will be found in the Appendix.

(b) Bins A, B, C and D.

These bins are situated in the panniers on each side of the hull. The door of each bin is closed at the top by two toggle clips, and is hinged at the centre and bottom. When open, the doors fold down on to the floor and do not foul the turret when it is being traversed. (See Photo 8).

Each bin holds 16 rounds of AP or HE ammunition, stowed in four layers of 4 rounds each. The layers are each supported by three fixed horizontal steel arms connected by transverse strips. Each arm is shaped to fit the underside of the rounds. The first round of each layer is prevented from rolling by two spring retainer bars fitted to the two arms supporting the case of the round. The remaining three rounds in each layer are held in position by similar retainer bars which are linked together and all three of which unlock as a single unit.

There is a danger of the loader jamming his fingers between the transverse strip and the round which he is removing from the rack; both of the loaders in the trials injured their hands several times in this way. The strips also impede removal of the rounds from the bin. Considering these disadvantages, the inclusion of the strips in the design of the bin seems of doubtful value.

The method of loading differs according to the position of the rounds in relation to the gun. Rounds in Bins A and C have their bases to the front and those in Bins B and D bases to the rear.

The nearest round in each layer is comparatively easy to load; however, as the loader empties the bin, it becomes increasingly difficult for him to remove the remaining rounds, first because they are so far back in the rack, secondly, because the supporting arms are fixed and impede the sliding of the rounds towards the loader, and thirdly because the transverse strips obstruct his hands as he draws the rounds to the front of the bin. A considerable amount of time is therefore wasted because the arms on top of the layer do not spring upwards, when not required, to allow greater access to the rounds in the lower layer.

Table 2 shows the loading times for Bin A in two positions; the times have been broken down into three elements:-

- (a) Opening the clips,
- (b) Grasping the round and removing it from the bin,
- (c) The remaining time, which consists of the loader bending down to the bin, straightening up, and ramming the round into the breech and operating the reset switch.

Table II

TRIAL 8						TRIAL 13					
Rd.	(a) Open Clips	(b) Procure Rd.	(c) Bend down and load	TOTAL	Rd.	(a) Open Clips	(b) Procure Rd.	(c) Bend down and load	Total		
1	2.0	1.5	3.6	7.1	1	1.7	1.8	7.1	10.6		
2	2.1	1.4	3.0	6.5	2	1.0	1.3	6.7	9.0		
3	1.5	1.6	2.4	6.5	3	1.0	2.1	6.2	9.3		
4	1.8	3.1	2.7	7.6	4	1.5	2.1	8.1	11.7		
5	3.5	5.5	2.6	11.6	5	1.6	4.8	6.5	12.9		
6	2.5	2.0	3.0	7.5	6	1.7	5.7	7.0	14.4		
7	2.5	8.2	1.2	11.9	7	1.9	5.3	6.2	13.4		
8	2.6	5.2	2.2	10.0	8	2.5	5.3	6.4	14.2		
9	-	5.0	3.9	8.9	9	-	5.6	6.4	12.0		
10	-	5.7	3.0	8.7	10	-	4.5	7.6	12.1		
11	-	6.3	2.2	8.5	11	-	3.1	7.2	10.3		
12	-	10.0	1.8	11.8	12	-	7.7	6.2	13.9		
13	-	6.7	2.7	9.4	13	-	4.6	7.2	11.8		
14	-	4.6	3.6	8.2	14	-	18.0	6.3	24.3		
15	-	7.2	2.9	10.1	15	-	4.6	5.8	10.4		
16	-	16.6	2.7	19.3	16	-	10.7	6.6	17.3		

It will be seen that the opening of the clips occupies between 1 and 2 secs., and the procuring of the round becomes progressively more difficult as the bin is emptied and therefore takes longer. Element (c) averages 2.8 secs. for Trial 8 and 7 secs. for Trial 13. In the former trial the bin was in its most accessible position with the turret at 11 o'clock, whereas in Trial 13, the bin was in its most inaccessible position, with the turret at 9 o'clock.

The rounds in Bins A (C) are stowed base forward and are to the left of the loader when he faces the bin. Thus, when he has procured a round from the bins his hands hold it in the correct position for loading. In the 11 (5) o'clock position, the bins are obstructed by a pillar supporting the floor and by a Jerrican containing water, and the rounds must be withdrawn base first. From 12 (6) o'clock to 1 (7) o'clock, the bins are free from obstructions; at 2 (8) o'clock, the bins are partially obstructed by the loader's seat and the rounds must be withdrawn from the bins nose first. There is an additional complication with Bin C; the turret lock makes it necessary for rounds from the top layer to be pulled out and then moved to the rear. This is prevented by the seat at 2 o'clock.

The round in Bins B (D) are stowed base to the rear and the loader when he has procured a round, must reverse it before he can load it into the gun. This extra movement is reflected in the average loading time for the four outer rounds, which is 8.5 secs. for these bins as against 7.4 secs. for Bins A and C.

In the 8 (2) o'clock position, Bins B (D) are obstructed by the pillar and Jerrican and the rounds must be withdrawn nose first. From 9 (3) o'clock, the bins are free from obstructions; at 11 (5) o'clock, the bins are partially obstructed by the loader's seat and the rounds must be withdrawn base first.

Footnote: * Items in brackets indicate Bin or Position 180° removed.

(c) Bins E, F, G and H.

These bins are situated under the hull floor and immediately in front of Bins A, B, C and D respectively. When the doors of any of the latter bins are open, they lie on the hull floor and prevent removal of the rounds from any of the corresponding floor bins in front of them. It is therefore unlikely that Bins E, F, G and H would be used while ammunition was still obtainable from any of the pannier bins.

Each of the floor bins holds four rounds of AP ammunition, stowed horizontally on top of each other. The rounds in Bins E and H are stowed base forward and those in Bins F and G base to the rear. The rounds are carried in wooden end supports, as shown in Fig. 2. The projectile supports pivot forward against the bin side and the base supports can be lifted up in a metal groove and dropped in the rear of the bin. This movement of the projectile supports allows the loader greater access to the lower rounds.

As the bins are arranged symmetrically on each side of the centre line of the hull, loading from Bin D at 11 o'clock is identical to loading from Bin G at 5 o'clock. It is therefore necessary only to study the two bins on the right side of the hull, i.e., Bins E and F.

Rounds in Bins E (G) can be loaded when the turret is at 12, 1 and 2 (6, 7 and 8) o'clock. Between 1 and 2 (7 and 8) o'clock, the bins are most accessible, and the top round can be loaded in an average of 5.5 secs. After removal of the first round, the end supports must be removed and the rounds are lower down and more awkward to handle. The average loading times for the 2nd, 3rd and bottom rounds are 7.7, 10.6 and 18.8 secs.

Rounds can be loaded from Bins F (H) when the turret is at 12, 11 and 10 (6, 5 and 4) o'clock. The bins are most accessible at 10 o'clock. The loading times from top to bottom rounds average 6.6, 11.0, 11.2 and 15.0 secs. respectively.

(d) Bin J.

This bin is under the floor on the right side of the hull and is not available until a trapdoor in the turret floor is lifted. Rounds can be removed from the bin only when the turret is at 12 o'clock, and the bin would be used solely for replenishment.

The bin contains two layers each of 3 rounds, all stowed horizontally. The innermost round in each layer is stowed base to the rear and the other two in each layer base forward.

Although the bin is for replenishment only, the rounds can be loaded direct to the gun when it is exactly at 12 o'clock. The average loading time per round is 6.4 secs., which includes the time taken to remove the wooden chocks separating each layer.

(e) Bin K

This bin is in the pannier on the left of the driver. It contains six rounds stowed horizontally base to the rear in three layers of 2 rounds each; the bin fittings are similar to those in the other pannier bins.

The rounds cannot be reached from the turret and are for replenishment only.

11 CONCLUSION

This vehicle has already proved its fighting qualities in action, and many reports have been written on its good and bad features.

From the motion study of the items studied the main features are as follows:-

The loader's position is the only really comfortable one; all the others are restricted and would cause discomfort.

The gunner's position and the layout and design of some of his controls are bad.

Loading times for the main armament are unnecessarily high by reason of the bad stowage design.

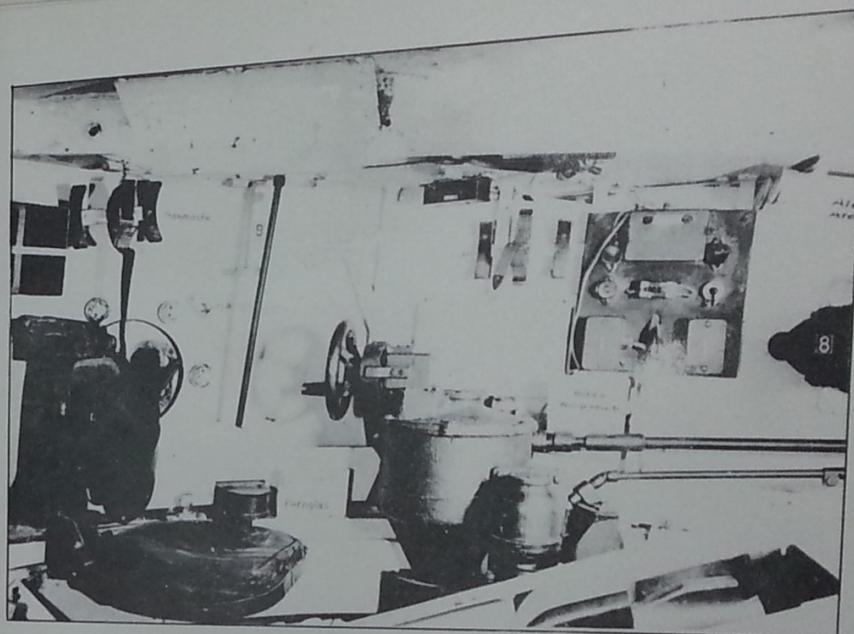
Listed below are the good and bad features of the vehicle's ammunition stowage, loading arrangements, and crew positions and controls:-

GOOD FEATURES

Availability of ammunition
Loader's seat and spacious position
Sprung roof hatch doors
Position of wireless set

BAD FEATURES

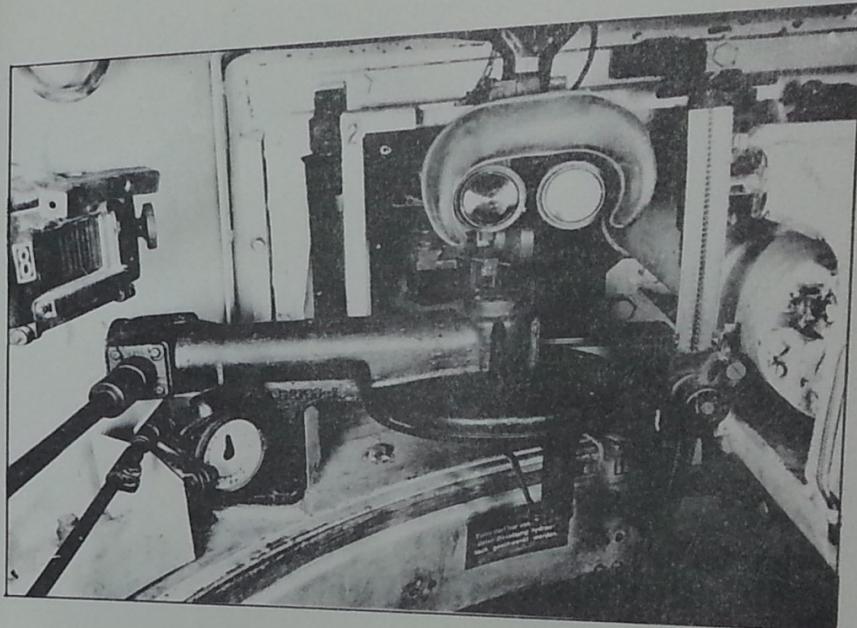
Gunner's cramped position
Commander's cramped position
Design of gun controls
Design of ammunition bins
High loading times
Difficulty of loading coaxial MG
Driver's and bow-gunner's feet are cramped.
Design of bow-gun mounting
Escape hatch cannot be closed from inside the turret.



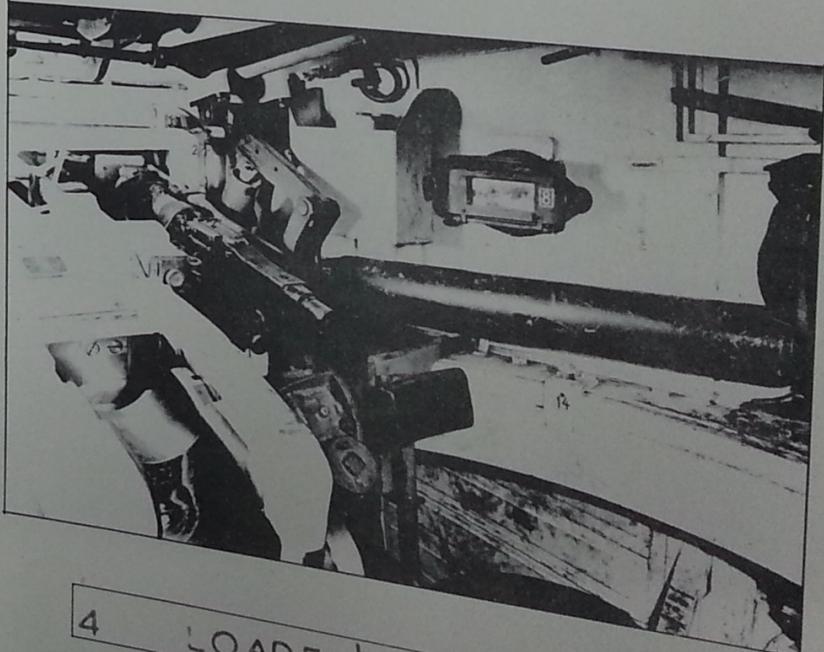
COMMANDER'S POSITION



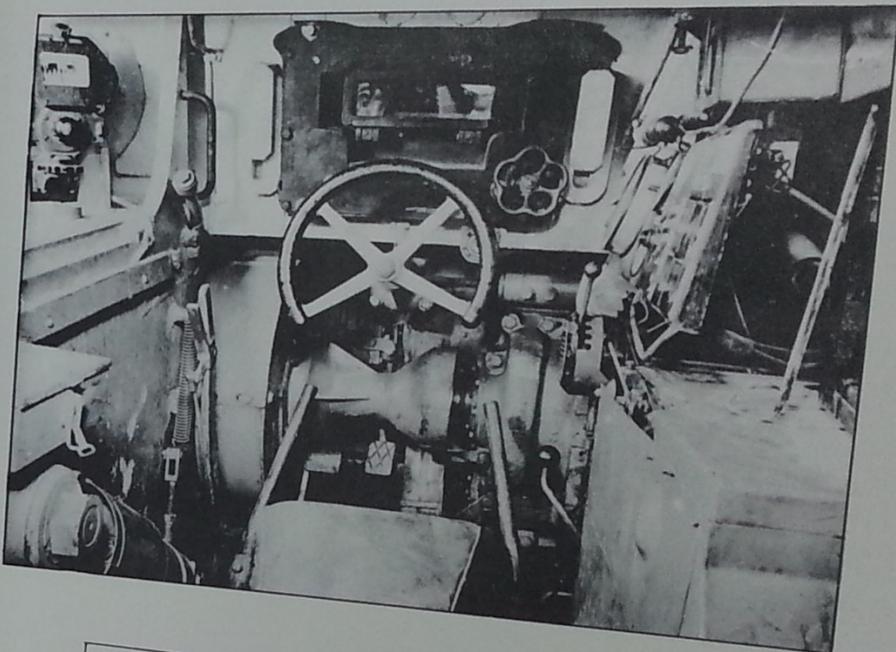
2 GUNNER'S POSITION



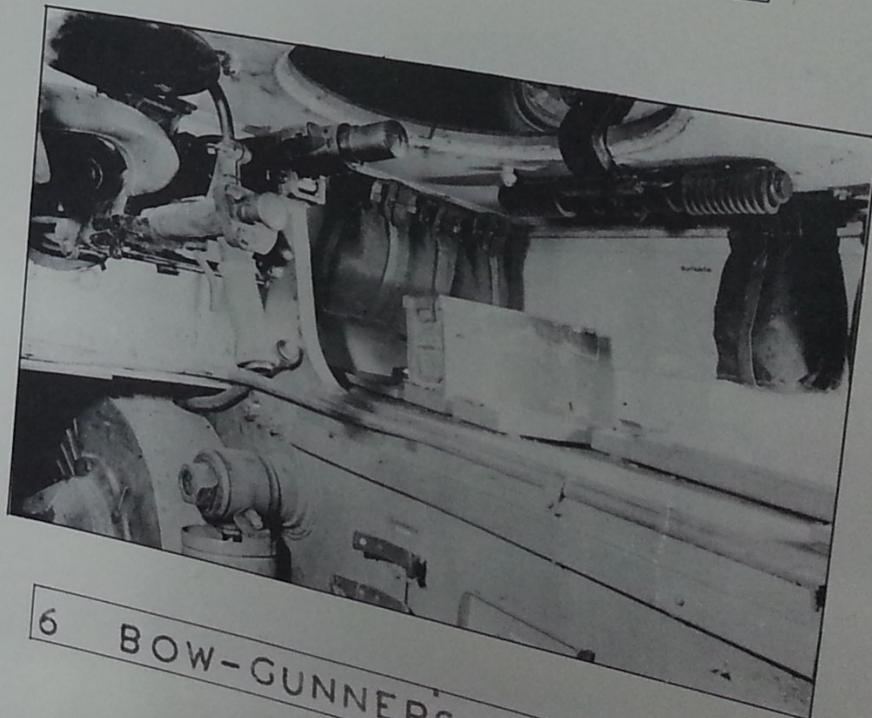
3 GUN CONTROLS



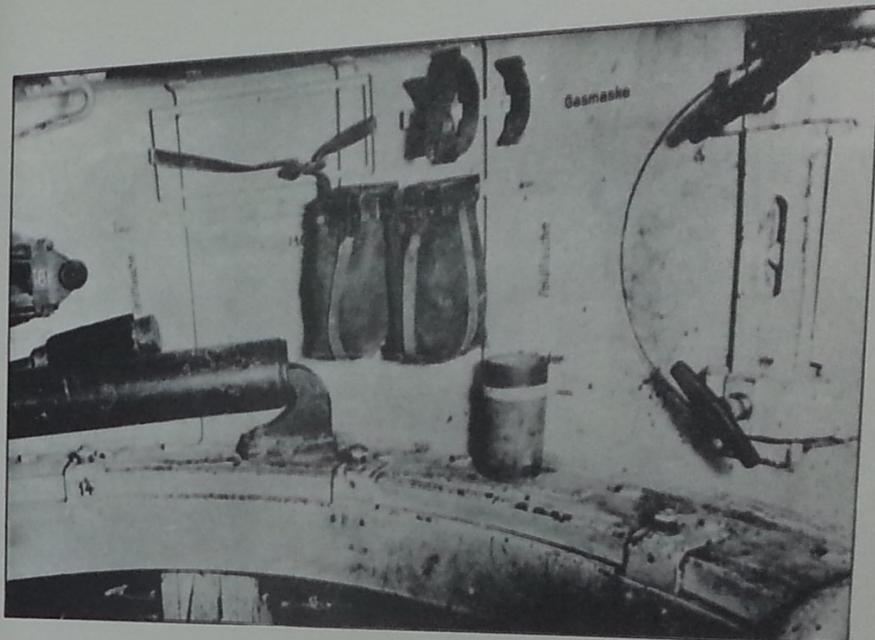
4 LOADER'S POSITION



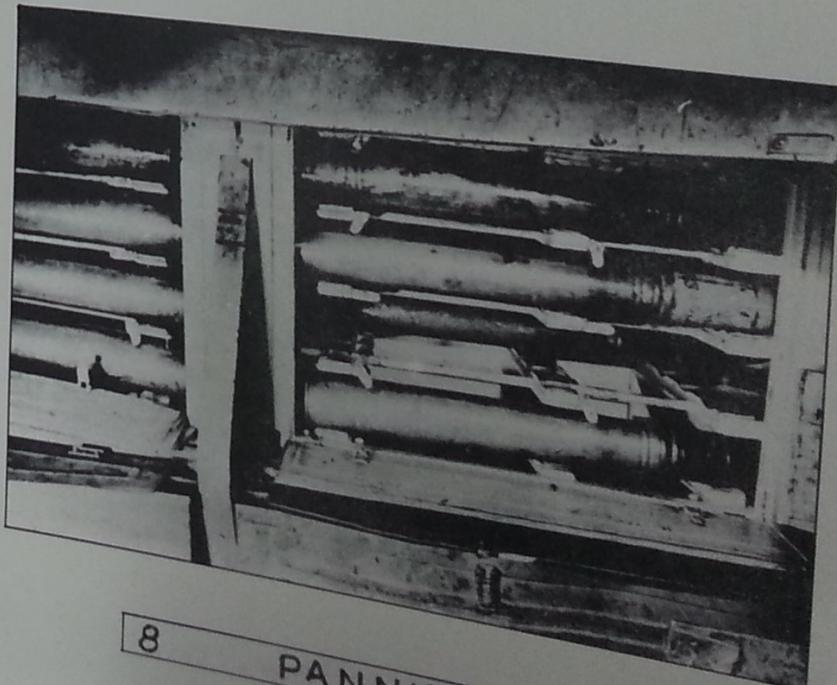
5 DRIVER'S POSITION



6 BOW-GUNNER'S POSITION



7 LOADER'S SIDE OF TURRET



8 PANNIER BINS

DETAILS OF LOADING TRIALS

Trial No.	4	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Turret	360°				350°					300°		270°			210°		
Posn.	120°/C				110°/C					100°/C		90°/C			80°/C		
Leader	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	A	A
Bin	A	B	A	B	A	B	A	B	A	B	B	B	B	B	C	C	C
Equiv.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Posn.	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Average	6.8	3.2	7.1	7.6	7.0	6.9	6.3	6.9	7.5	7.7	7.2	6.6	10.2	12.4	12.3	11.1	8.3
1st 4	13.3	16.5	13.0	16.7	12.4	16.1	11.0	11.0	16.3	12.6	19.7	11.8	15.9	16.2	-	-	-
average	7.0	7.5	7.7	0.7	7.0	7.5	0.0	7.1	7.4	3.7	7.5	0.9	10.6	13.0	11.8	-	15.0
Last 4	13.3	16.5	13.0	16.7	12.4	16.1	11.0	11.0	16.3	12.6	19.7	11.8	15.9	16.2	-	-	-
Rd.1	6.3	5.0	6.4	3.0	6.9	7.2	5.8	5.8	6.5	6.5	7.2	7.1	9.0	9.0	10.0	9.2	-
Rd.2	5.9	7.8	6.2	6.4	6.2	6.7	5.4	6.5	6.2	7.0	7.0	3.5	9.2	9.7	10.0	-	-
Rd.3	7.0	9.5	7.0	9.0	7.3	9.1	6.2	6.2	7.1	7.3	7.9	7.0	6.0	11.7	15.3	11.3	6.9
Rd.4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rd.5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rd.6	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rd.7	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rd.8	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rd.9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rd.10	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rd.11	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rd.12	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Rd.13	16.5	15.6	9.8	16.7	16.4	12.0	11.6	9.4	16.4	10.1	31.0	12.3	13.9	-	-	-	-
Rd.14	12.8	11.0	9.2	13.1	12.1	8.2	9.5	8.2	9.2	16.0	14.0	12.7	11.8	16.8	-	-	-
Rd.15	12.0	16.0	16.1	13.2	11.2	33.5	12.0	10.1	10.1	12.2	11.0	10.2	10.4	14.9	17.0	-	-
Rd.16	12.0	23.7	16.7	23.8	9.9	10.5	10.7	19.3	29.4	11.9	18.6	12.1	17.3	18.2	12.5	15.4	-

Note: Owing to difficulties in reproduction this table has been re-arranged to read vertically instead of horizontally.

		DETAILS OF LOADING TRIALS CONT.			
Trial No.	18	19	20	21	22
Turret Posn.	225°	210°	180°	150°	120°
Loader Bin	750/c	70/c	60/c	50/c	40/c
Bin Equiv.	A	A	B	A	C
Posn.	C	C	C	D	D
Average	-	-	-	Rack A at 360°	Rack A at 330°
1st 4	6.7	7.2	6.8	Rack B at 360°	Rack B at 330°
Average	-	-	-	Rack A at 360°	Rack B at 330°
Last 4	14.6	9.1	9.1	Rack B at 360°	Rack B at 330°
Rd.1	-	5.9	7.7	Rack A at 360°	Rack B at 330°
Rd.2	9.8	7.4	6.0	Rack A at 360°	Rack B at 330°
Rd.3	6.6	6.4	6.1	Rack A at 360°	Rack B at 330°
Rd.4	7.5	6.2	6.1	Rack A at 360°	Rack B at 330°
Rd.5	-	-	-	Rack A at 360°	Rack B at 330°
Rd.6	-	-	-	Rack A at 360°	Rack B at 330°
Rd.7	-	-	-	Rack A at 360°	Rack B at 330°
Rd.8	-	-	-	Rack A at 360°	Rack B at 330°
Rd.9	-	-	-	Rack A at 360°	Rack B at 330°
Rd.10	-	-	-	Rack A at 360°	Rack B at 330°
Rd.11	-	-	-	Rack A at 360°	Rack B at 330°
Rd.12	-	-	-	Rack A at 360°	Rack B at 330°
Rd.13	-	-	-	Rack A at 360°	Rack B at 330°
Rd.14	16.6	12.0	10.6	Rack A at 360°	Rack B at 330°
Rd.15	16.0	9.3	9.7	Rack A at 360°	Rack B at 330°
Rd.16	11.2	7.9	22.0	Rack A at 360°	Rack B at 330°

Note: Owing to difficulties in reproduction this table has been rearranged to read vertically instead of horizontally.

DETAILS OF LOADING TRIALS CONT.	
Trial No.	Posn.
23	24
Posn.	270°
Loader	25
Bin	225°
Equiv.	26
Posn.	A
1st 4.	B
Average	A. B. F.
1st 4.	180°
Average	27
10.1	360°
Average	11.7
Last 4	8.6
Rd.1	13.9
Rd.2	12.5
Rd.3	Average top 3
Rd.4	Average bottom 3
Rd.5	11.0
Rd.6	11.5
Rd.7	11.0
Rd.8	10.8
Rd.9	10.5
Rd.10	12.5
Rd.11	12.5
Rd.12	12.9
Rd.13	14.8
Rd.14	14.5
Rd.15	12.9
Rd.16	12.5

POSITION OF ROUNDs IN BINS
BINS A, B, C & D. BINS D, E, F & G.
BIN J
 1 5 9 13 2 6 10 14
 3 7 11 15 4 8 12 16
 1 2 3 4 5 6
 4 5 6

Note:

Owing to difficulties in reproduction vertically instead of horizontally, this table has been re-arranged to read vertically.

SECTION 3.

MOTION STUDY OF THE 'ROYAL TIGER'

SECTION 3.

MOTION STUDY OF

Pz.KPFW. VI(B) "TIGER" FUR 8.8cm. KW. K.43 L/71 (Sd.Kfz.182)
(THE "ROYAL TIGER")

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MOTION STUDY OF THE 'ROYAL TIGER'

1 DESCRIPTION OF THE VEHICLE

The Pz Kpfw VI(B) is commonly known as the Royal Tiger. It weighs approximately 70 tons in battle order. It mounts an 8.8cm. Kw K 43 gun and a 7.92mm MG 34 in the turret, and a hull MG 34 is mounted in the glacis plate.

The vehicle is 23' 10" long, 12' 0" wide and 10' 2" high; the turret ring is 6' 3" in diameter. The five members of the crew are the commander, gunner and loader in the turret, and the driver and bow-gunner in the hull.

The vehicle studied was F.V.D.D. No. 3234, an early model in reasonably good condition.

2 THE COMMANDER

(a) Seat and Positions. The commander's station is in the left rear quarter of the turret. He has three alternative positions; first, seated in the seat, secondly, standing on the footrests, and thirdly, standing on the turret floor.

The seat is saddle-shaped and the top is 11" long and 1' 2 $\frac{1}{2}$ " wide and covered with imitation leather. (See Photo 1.) It is mounted on a hinged arm on the turret wall and can be stowed against it when not required. No other adjustment is provided.

The backrest is also covered with imitation leather, and is 11" wide and 4" high. It is hinged, and can, like the seat, be stowed against the turret wall when not required. It is badly positioned in relation to the seat, since it is mounted so far forward that it tends to push the commander off the seat. This tendency would become more pronounced when the vehicle was on the move.

The commander's left footrest is hinged and can be folded against the turret wall when not required. His right footrest is fixed to the right side of the gunner's backrest. When the commander uses the footrests, he can stand in relative comfort.

(b) Vision. The commander's vision facilities are reasonable. When seated, he can see with comfort through any one of the set of seven episcopes mounted in his fixed cupola. When standing on the footrests, his head and shoulders are outside the turret and his vision range is reasonable. However, when standing on the turret floor, a commander of average size cannot see either out of the turret or through the episcopes. He would therefore use his seat or footrests when the vehicle was in action.

(c) Conclusion. The commander's position is spacious and comfortable, although the backrest to his seat is mounted too far forward. His vision facilities are reasonable.

3 THE GUNNER

(a) Seat and Position. The gunner sits on the left of the main armament and in front of the commander. His seat is saddle-shaped, padded and covered with imitation leather. It is 11" long, 1' 0 $\frac{1}{2}$ " wide and 1' 6 $\frac{1}{2}$ " high, mounted on the turntable, and not adjustable. (See Photo 2.)

The backrest is curved and padded. It is 11" wide and 5" high and can be lifted on a hinge on its right side to allow the gunner greater access to his seat.

Both the seat and backrest are satisfactory, but the position is cramped and uncomfortable. This is due to the bad layout and design of the gun controls, which are described below.

(b) Gun Controls. The traverse handwheel is very badly positioned. When the gunner is seated, the linkage between the wheel and the gearing is between his knees, which must be kept apart. In such a cramped station, the gunner would soon become very uncomfortable and probably fatigued.

The handwheel is $10\frac{1}{4}$ " in diameter and the handle is $3\frac{3}{4}$ " long. A lever on the forward end of the gunner's seat operates a cam, which allows adjustment of the handwheel forwards and backwards through an arc. The wheel can be locked in the required position. We found that the best position was in an almost horizontal plane, with the front rim of the wheel lower than the rear. Even in this position, the rear rim chafes the gunner's wrist when he turns the wheel. In general, the control is very unsatisfactory, since in any position it is uncomfortable to use.

Fortunately for the gunner, the turret can also be traversed by power. There are two controls which can be used either independently or, as is more likely, together. The first control is a tilting foot-plate which is let into the floor in front of the gunner's seat. The plate is 1' 1" from front to back and 1' 0" wide, and is pivoted along its length. It can be locked in the neutral position when not required.

The axis of the plate is mounted approx. 6" to the right of the centre of the gunner's seat, and traversing is difficult in either direction. On left traverse, the gunner's left foot depresses the left half of the plate; this is awkward because the gunner's left leg jams against the traverse handwheel spindle. On right traverse, the side of the gunner's right boot scrapes against the side of the hole cut into the turret floor and his boot tends to slip off the plate. The plate inspected was stiff to operate independently, though when used in conjunction with the hand lever, it proved more satisfactory. The hand lever is a plain steel bar mounted on the left side of the seat. The bar is operated by moving it either forwards (left traverse) or backwards (right traverse), and it is mounted on the same linkage as the footplate. When the bar is pulled backwards, the gunner's left elbow tends to strike the commander's left footrest.

Although more satisfactory than just a footpedal, the combination of footpedal and hand lever is still, in our opinion, not as efficient as the spade-grip type of control.

The elevating handwheel is $9\frac{1}{2}$ " in diameter and mounted in a vertical plane to the right of the gunner's seat. (See Photo 2.) The 3" long handle is too short to be gripped by the whole hand. When the handle is at the bottom of its arc of movement, the gunner's right hand tends to jam on a lever on the power traverse gearbox, as there is only 1" clearance between the two.

The gun is fired electrically. The trigger comprises a steel bar hinged to the shaft cover of the elevating wheel. The bar is curved and lies parallel to the rim of the wheel. It is operated (satisfactorily) by the gunner's right hand.

No emergency firing gear was evident in the vehicle inspected.

(c) Sighting and Vision. The sight, type TZF 9d, is articulated at the front end and the eyepiece is clamped to the turret roof. (See Photo 3.) The sight is mounted about 4" to the right of the seat centre line and the gunner must therefore lean to the right when sighting. The browpad inspected was very hard, and the gunner would be liable to injure his nose on the eyepiece when sighting 'on the move'.

The clinometer position (on the right of the sight) is satisfactory, and the traverse indicator dials can be seen without removing one's head from the sight.

No vision device other than the sight is provided for the gunner.

(d) Conclusion. The gunner's position is very unsatisfactory. It is cramped and uncomfortable and some of the controls are badly positioned. The hand and power traverse controls are badly designed, and the gunner is given inadequate vision equipment.

4. THE LOADER

(a) Seat and Position. The loader's station is on the right of the main armament. A mounting in the front part of his station indicates that he is provided with a seat, but no such seat was available in the vehicle inspected. Its probable position is in the centre of the right half of the turret.

As it appears from the mounting that the seat is removable, the designer's intention would seem to have been that the seat would be removed during an action to allow the loader greater access when loading. It would be replaced only when immediate loading was not anticipated.

The loader has ample space for handling ammunition on his side of the turret. In addition, if his hatch is open, a loader whose height is 5' 7" or less can stand erect with his head not touching the turret roof. However, when the hatch is closed, the fittings on the inside of the door project about 3" below the level of the roof. Since the loader would probably strike his head against them when loading he would probably keep the hatch door open when loading.

(b) Controls. An auxiliary traverse handwheel is provided for the loader so that he can assist the gunner to traverse the turret when the power traverse mechanism is not being used. A latch on the gunner's wheel prevents the loader from operating his wheel independently.

The loader's handwheel is 10" in diameter and mounted with the front rim higher than the rear. The 3" handle is too small to be gripped by the whole hand, and the angle at which the wheel is mounted makes its operation awkward and tedious. Mounting the wheel in a vertical plane would have been more satisfactory.

(c) Vision. The sole vision device provided for the loader is a 5" wide episcopic mounted in the turret roof above the coaxial MG 34. (See Photo 3.) This seems satisfactory, and moreover it does not project into the loader's station.

(d) Conclusion. The loader's position is very spacious and allows adequate room for loading the large ammunition. The auxiliary handwheel is badly positioned and awkward to operate. The loader has adequate vision facilities.

5. THE DRIVER

(a) Seat and Positions. The driver's position is in the front left quarter of the hull. The seat is padded and 1' 2" square, and the height

can be adjusted so that he can drive 'closed-down' (lower position) or 'opened-up' with his head and shoulders outside the hatch (upper position).

The padded backrest is 1' 0" square and its angle can be adjusted by a cam, which is locked by a lever on the right side of the seat. Both the seat and backrest are comfortable.

(b) Controls. Since the seat is adjustable for upper and lower positions, the controls have been designed to be accessible when the driver is in either position.

Power-assisted steering is controlled by a semi-circular wheel 1' 3" in diameter. The wheel column is jointed and the wheel can be raised or lowered to suit the driver's position. The wheel column is also telescopic and can be extended through 11" as required.

In general, the wheel is very satisfactory, and more comfortable to use than the orthodox steering levers fitted in most A.F.V's.

A disadvantage, however, is that the wheel is effective only for power-assisted steering. If the power system is not running, (e.g. when the vehicle is being towed), the usual manual steering is used. This is controlled by two standard steering levers, each 1' 9 $\frac{1}{2}$ " long, mounted on the hull floor, one on each side of the driver's legs. The levers are accessible only when the driver is in his lower position, and valuable space is required for two sets of steering controls. The driver's hand is liable to catch on the gearbox direction lever as he pulls back the right steering lever.

The preselective gearbox gives 8 forward and 4 reverse ratios. The control lever is a short rod with a knob at the top end, and is mounted in a semi-circular 'gate' on top of the gearbox on the right of the driver, who does not have to use the clutch pedal when changing gear, and who has no need to 'rev-up' when changing down. Both of these operations are performed automatically by the gearbox, the clutch pedal being used only for engaging a gear before the tank moves off.

The handbrake is a heavy-duty ratchet type and is operated by pulling towards the rear. Though the brake lever is mounted on the left of the driver, the two hands would probably be needed to pull the brake 'hard-on', since the return spring is very powerful.

The foot controls are arranged in the order clutch, footbrake and accelerator from left to right. The clutch and footbrake pedals are identical, being 3 $\frac{1}{2}$ " long and 2" wide. Both are quite satisfactory to use and can be quickly adjusted (by means of jointed pedal arms) to either the upper or lower position.

Two separate accelerator pedals are provided. The lower control is a plate 3 $\frac{1}{2}$ " wide and 10 $\frac{3}{4}$ " long, which is pivoted to the floor. The pedal is almost vertical and consequently difficult to operate. The upper control is a roller 4" long and 1 $\frac{1}{2}$ " wide mounted on a common linkage with the lower pedal. A hinged plate 4 $\frac{1}{2}$ " wide which can be folded when not in use, is fitted as a footrest. The pedal is rather difficult to find with the foot but is otherwise satisfactory.

(c) Vision. When driving 'opened-up' the driver has an adequate vision range, since his head and shoulders are outside the hull of the tank. When the vehicle is being driven 'closed-down' his sole vision device is a 5" wide episcopic. A handle on each side of its mounting is used to control the episcopic's angle of tilt and rotation. Although the driver can see the ground from 6 yds. onwards in front of the vehicle, the fitting of only one episcopic for the driver of so large a tank is bad.

The vision range with the episcopes is so restricted that, probably, even an experienced driver would have to rely on his commander's instructions when driving 'closed-down' along a narrow or devious route. This is undesirable, as the commander should at all times be free to look for targets, instead of concentrating on whether or not the driver is keeping the correct course.

(d) Conclusion. The driver's seat and positions are comfortable and his controls are mostly satisfactory. His vision range when driving 'opened-up' is excellent, but inadequate when he is in the lower position.

6. THE BOW-GUNNER

The seat was missing and the bow-gun could not be fitted in the vehicle inspected. Therefore there is little which we can say about the bow-gunner's position. The seat is presumably similar to the driver's except that it is probably not adjustable for height.

The spacious position would probably be comfortable, but the long drop from the hatch to the seat would make "baling-out" rather difficult.

7. LIGHTING

Festoon lamps are fitted

- (i) Above the gunner's position
- (i') Above the coaxial MG 34
- (iii) On the roof in front of the commander's cupola
- (iv) On the driver's dashboard
- (v) On the wireless set.

Thus a lamp is fitted in each crew member's station. The arrangement is reasonable, although the fitting of a lamp in the turret bulge would have facilitated loading when the tank interior was dark though still light enough outside.

8. CREW ACCESS

(a) Hatches. The commander's fixed 'cupola' is circular, 1' 7" in diameter and is situated in the left rear quarter of the turret roof. (See Photo 4.) In this cupola are fitted the seven episcopes the commander looks through when seated. Although fairly deep, the cupola allows quick access to and from the turret. The cupola door is pivoted, and lifts and swings sideways to open. When the door is open, it does not increase the overall height of the tank. The door can be closed from inside or outside the tank, but can be locked only from inside.

The other turret roof hatch is on the right side and is for the loader. (See Photo 4.) The hatch is rectangular, 1' 2" long and 1' 8" wide and opens with spring-assistance. It is locked by a set of levers operated by a handwheel on the inside of the door. This seems a cumbersome arrangement and moreover probably a dangerous one since the levers project below roof level when the door is closed. They obstruct the loader, who is liable to injure his head on the projections when loading.

A turret escape hatch is fitted into the rear wall of the turret and is 1' 8" wide and 1' 2" high. (See Photos 5 and 6.) When the

turret bulge ammunition bins are full, the rounds project around and beneath the hatch, making evacuation almost impossible, even for a slim crew member. (See Photo 9.) When the bins are emptied (a situation which would be operationally dangerous) the hatch is more accessible, but can still be used only by a very thin man. In emergency, the crew members would probably prefer to risk getting out 'with the smoke' through the roof hatches rather than chance being caught in the escape hatch or on one of the many projections surrounding it.

A circular empty-case ejection hatch 9" in diameter is fitted in the turret roof towards the rear. The hatch can be closed and locked when not required.

The driver's hatch is mounted in the hull roof on the left side of the vehicle front. It is 1' 2 $\frac{1}{2}$ " long and 1' 6 $\frac{1}{2}$ " wide and, like the commander's hatch, opens on a pivot by swinging sideways. When open, the door does not foul the turret on traverse. The door can be opened and closed from inside the vehicle, and is very satisfactory from a user aspect.

The bow-gunner's hatch is identical to the driver's but is mounted on the right side of the hull roof and opens in the opposite direction from the driver's. (See Photos 7 and 8.)

(b) Baling-Out! The men taking part in the loading trials took the following times (in seconds) to leave their stations and get outside the vehicle:-

	Condr.	Gunner	Loader	Dvr.
Hatch open	5	10.3	6.7	3.4
Hatch closed but not locked	10.2	14.1	9.8	6.9

Since no bow-gunner's seat was fitted, no trial could be made from that position.

Three men were timed leaving the turret via the escape hatch. The biggest became entangled in the bin arms and could not move either way until he was released from inside the turret. The other two men took 13.4 and 15 secs. respectively, the faster man tearing his clothing 'en route'. These trials took place with the men standing in the loader's station, and with no ammunition in the bulge bins, i.e., under the best possible conditions.

(c) Conclusion. The commander's, driver's and bow-gunner's hatches are all well-designed and satisfactory; the loader's hatch door fittings project inside the turret when the door is closed; and the escape hatch is almost useless for 'baling-out' and its principal use would be for stowing the turret bulge bins from outside the turret.

9. MAIN ARMAMENT LOADING TRIALS

(a) Loading Arrangement. Fig. I shows the position of the ammunition stowage in the vehicle, and a full list of loading trials and times will be found in the Appendix.

Although the documents stated that a total of eighty 8.8cm rounds was carried in this vehicle, we found a stowage for only 64 rounds in the earlier vehicle and 70 rounds in the later model. In both vehicles, 48

FIG. I

ROYAL TIGER.
PLAN OF AMMUNITION STOWAGE.

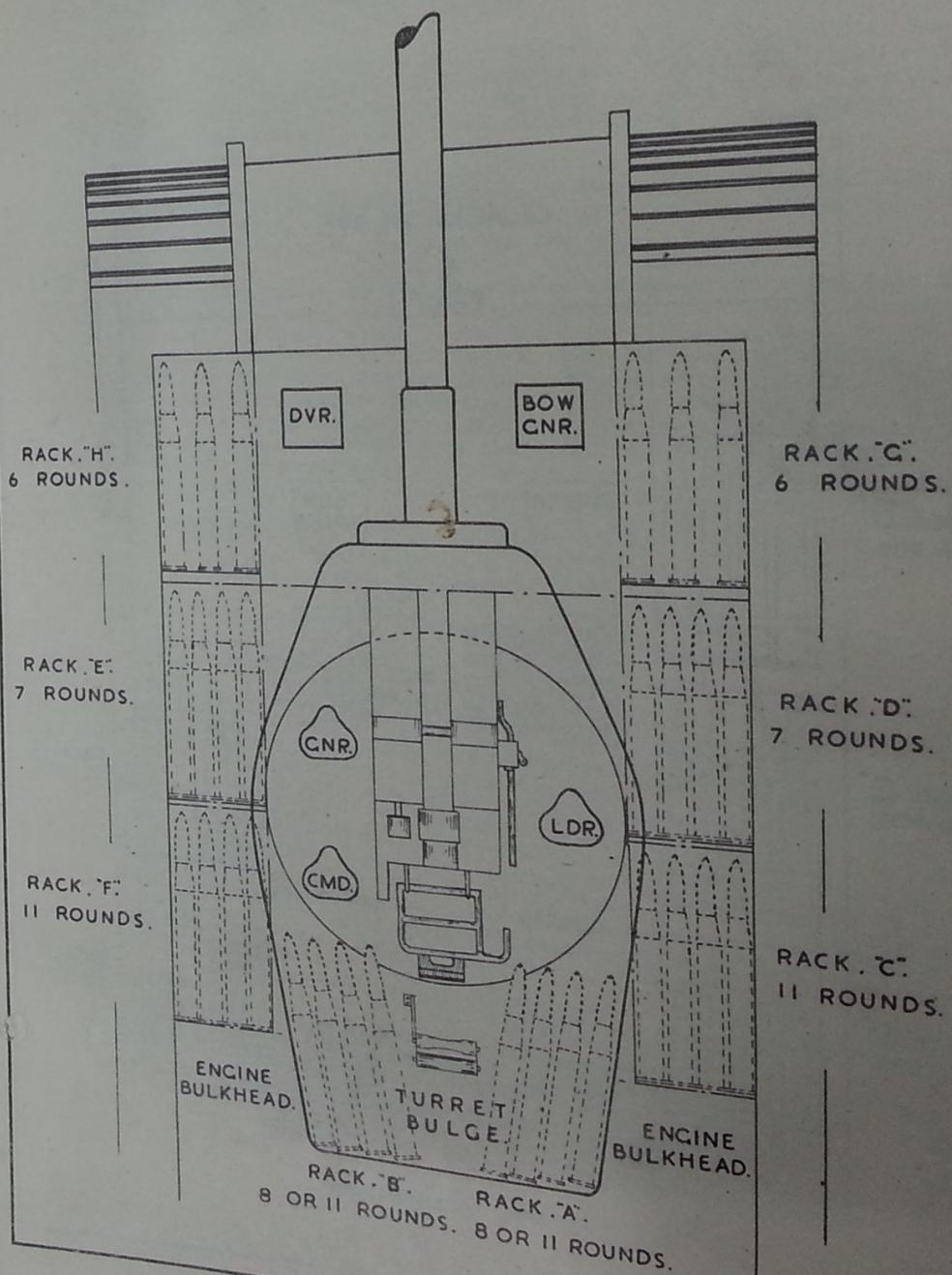
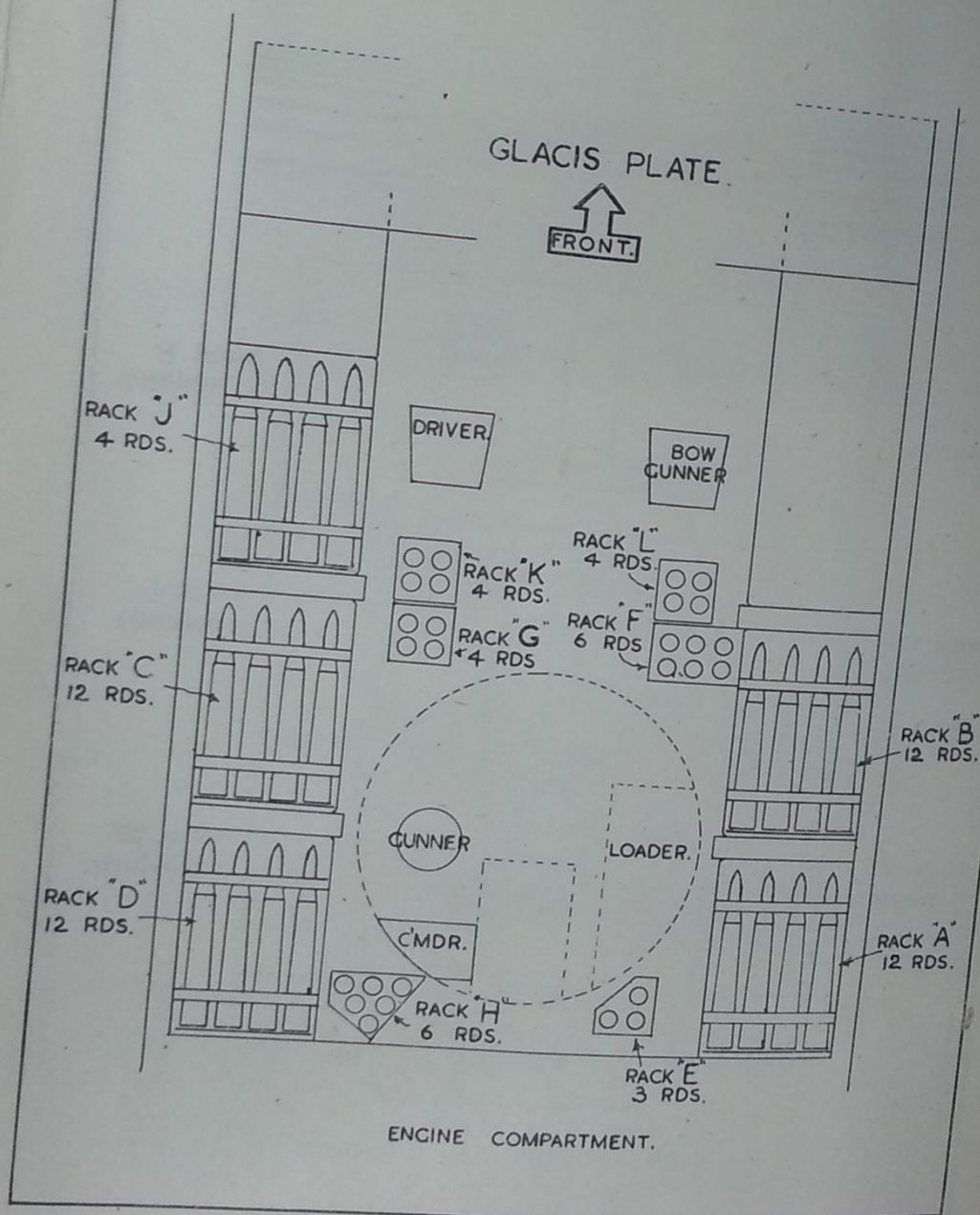


FIG 1

'PANTHER'
PLAN OF AMMUNITION STOWAGE.



rounds are carried in the panniers and the remainder in two racks in the turret bulge. All the rounds are stowed horizontally with bases rear.

When the gun fires, the empty case is ejected but does not drop clear of the deflector guard. Instead, it lies with the base on the deflector guard and the neck on the breech ring. It must therefore be removed before another round can be loaded. In the trials, the cases were thrown through the ejection hatch in the turret roof. This took an average time of 2.4 secs. per case.

Although the loader would probably wear gloves when handling the hot case, none were available for the trial. The loading times would not be materially increased by wearing gloves, since the rounds are more or less 'man-handled' into the gun and no special finger dexterity is required.

Loading is simplified by the use of a collapsible roller, which is shown in Photo 9. The roller is hinged on to the bulge floor between the two bins and is in line with the gun.

When the gun is elevated, the loader can insert the round into the breech comparatively easily since the deflector guard is low down and allows him a straight push. (See Photo 11.) However, when the gun is depressed, the deflector guard is well above the level of both the loading roller and the breech, making loading very awkward and difficult. (See Photo 12.) The easiest and fastest drill for loading the gun in depression was to remove the empty case, drop the hinged deflector guard, load the round, replace the deflector guard and operate the safety switch. If this drill is not used, the loader is liable to lose control of the round (weighing 51 lbs.) and jam his fingers on the deflector guard.

The four loaders used in the trials were:-

Loader A - Tpr. Egan, height 5' 4",

Loader B - Cpl. Francis, height 5' 10",

Loader C - Cfn. Weaver, height 6' 4" and

Loader D - Dvr. Liddiatt, height 6' 1".

(b) Turret Bulge Racks. The two 'ready' racks in the vehicle are Racks A and B which are situated in the turret bulge. (See Photo 13.) Rack A is in the right side of the bulge (nearer the loader) and Rack B is in the left side. Each rack in the earlier vehicles holds 8 rounds, and in the more recent vehicles 11 rounds. The rounds are stowed in three layers, each layer resting on two fixed arms. Each round is individually held in position by two steel straps fastened by toggle clips. Although this arrangement keeps the rounds securely in place, the rear-most clips are not easily accessible and time is lost both in fastening and unfastening each round.

The drill for loading from either rack is - remove the empty case from the gun and throw it through the ejection hatch, move to the rack, undo the toggle clips holding the round, roll the round along the rack arms, lift (or drop) the round onto the roller, holding the ogive by the right hand, pull the round forward on the roller, and guide the projectile into the breech, still holding the ogive by the right hand, push the base of the round with the left hand, lifting it clear of the roller and the deflector guard, and ram the round home. Operate the safety switch with the right hand.

The average loading times per round (in seconds) are as follows:-

RACK	GUN LEVEL	MAX. ELEV.	MAX. DEPR.
A	9.6	8.2	10.1
B	8.0	8.0	9.3

Although Rack A is nearer to the loader than Rack B, rounds can be loaded faster from Rack B because the rack is directly opposite to the loader. Consequently, the clips are more accessible and the rounds are easier to remove. However, Loader A, who is 5' 4" tall, could not reach two of the rounds in Rack B.

Since the racks hold a total of either 16 rounds (earlier model) or 22 rounds (later model), they would provide adequate 'ready' ammunition for any normal engagement. They would be replenished from one of the pannier racks.

(c) Pannier Racks. There are three pairs of pannier racks, C and F, D, and E, and G and H. In these racks, the rounds are stowed horizontally in layers, bases to rear, with each layer resting on three rigid arms. Two of these arms carry hinged wooden blocks, which wedge against the underside of the rounds and keep them in position. The hinges on these blocks easily get rusty and dirty and then require considerable force to operate. This is undesirable, since it leads to increased round-handling times.

This type of stowage would have been greatly improved if the layer arms had been hinged and sprung so that they lifted upwards when the rounds were removed. This would have allowed greater access to the layer below.

Racks C and F. The position of these racks is shown in Fig. I. Each rack is designed to hold 11 rounds in three layers, but in the vehicle inspected, only 8 rounds could be stowed. As will be seen in Photos 14 and 15, a curved rail has been fitted on the hull roof to carry 7.92 mm ammunition belt bags for the coaxial MG 34. Each end of the rail projects into one of the racks and prevents the top layer of three rounds from being stowed. In addition, when the rail is loaded with belt bags, the centre layer of the bin is partly obscured.

The rail appears to be an afterthought, and its designers presumably considered that it would be better to have a large stock of MG 34 ammunition, and lose stowage space for six 8.8 cm rounds.

The two racks A and B contain an adequate number of rounds (16 or 22) for any normal engagement. Eight rounds were loaded from Rack G with the turret at 12 o'clock, in an average loading time per round of 17.8 secs.

Racks D and E. Racks D and E are situated in front of racks C and F respectively, as shown in Fig. I. The racks each hold 7 rounds in two layers. The rounds are even less accessible than those in racks C and F.

Racks G and H. These racks are situated on each side of the extreme front of the hull. Each rack holds 6 rounds in two layers of three rounds each. Replenishing racks A and B from these racks would be very awkward and fatiguing.

10 CONCLUSION

The Royal Tiger allows a very reasonable degree of comfort to all the crew members except the gunner. His seat is badly positioned in relation to his controls, his position is cramped and not easily accessible and the gun traverse controls are badly designed.

The loading arrangement is good; the loader has a spacious position, and the ready rounds need not be lifted appreciably when loading. The arrangement should be compared with the U.K. tank arrangement having no rounds stowed above the level of the turret ring. This latter is probably safer, but it makes the loading of large and heavy rounds very slow and fatiguing to the loader.

Despite the good loading arrangement, the loading times are high in this vehicle, because:-

- (a) The empty case must be disposed of before another round can be loaded.
- (b) The design of the rack fittings is unsatisfactory.
- (c) The extreme size and weight of the rounds makes them awkward to manœuvre.

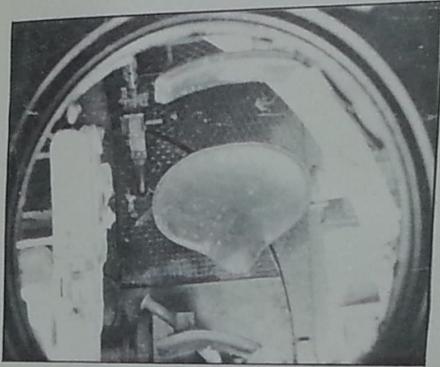
The following are the outstandingly good and bad features of the vehicle as revealed by this Motion Study:-

GOOD FEATURES

- (i) Very few projecting fittings in fighting compartment.
- (ii) Driver's seat and two positions. Steering wheel.
- (iii) Driver's and bow-gunner's hatch doors.
- (iv) Driver's opened-up vision.
- (v) Loading roller in bulge.
- (vi) Number of 8.8cm rounds stowed.

BAD FEATURES

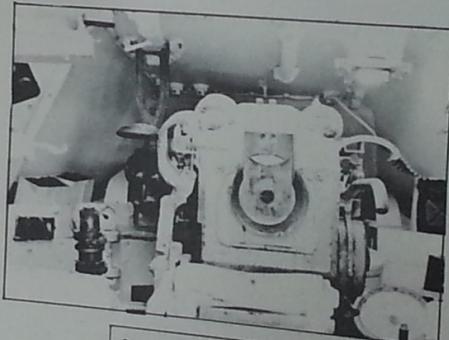
- (vii) Commander's backrest.
- (viii) Position of gunner's seat.
- (ix) Gunner's cramped station.
- (x) Gun traverse controls.
- (xi) Position of loader's handwheel.
- (xii) Loader's hatch door.
- (xiii) Driver's closed-down vision.
- (xiv) Design of ammunition rack fittings.
- (xv) Empty case must be removed before next round can be loaded.
- (xvi) Rail for stowing MG 34 belt bags fouls Racks C and F.



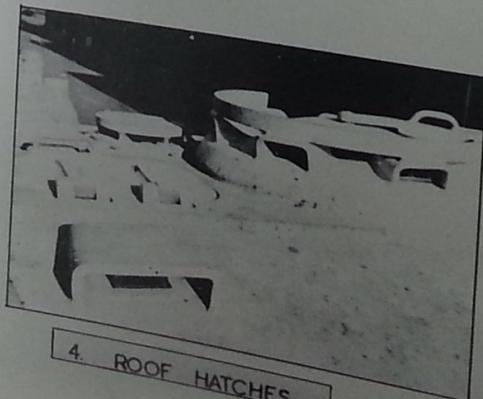
I. COMMANDER'S POSITION.



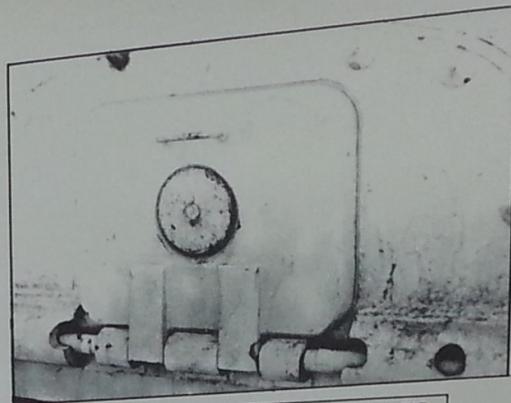
2. GUNNER'S POSITION.



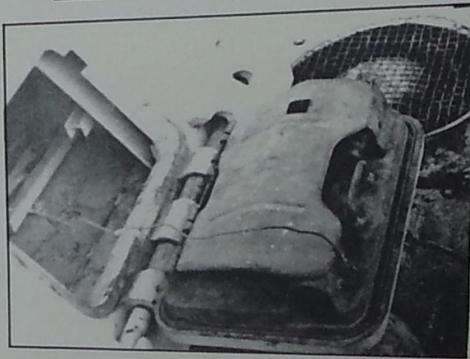
3. MAIN ARMAMENT.



4. ROOF HATCHES.



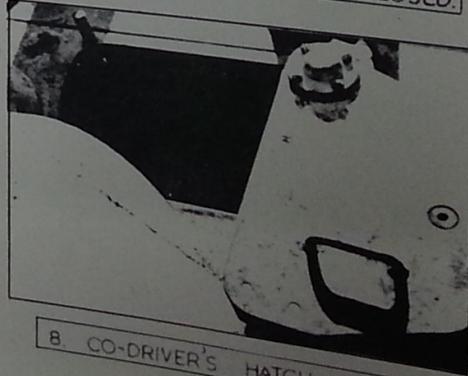
5. ESCAPE HATCH CLOSED.



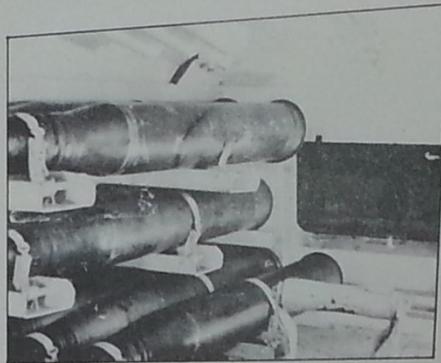
6. ESCAPE HATCH OPEN.



7. CO-DRIVER'S HATCH CLOSED.



8. CO-DRIVER'S HATCH OPEN.



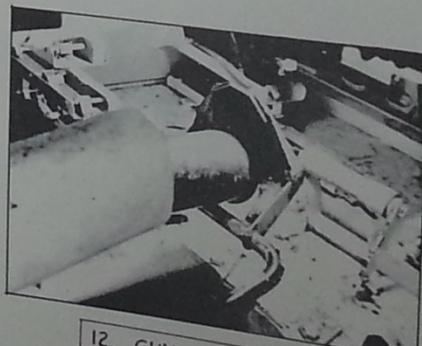
9. ESCAPE HATCH.



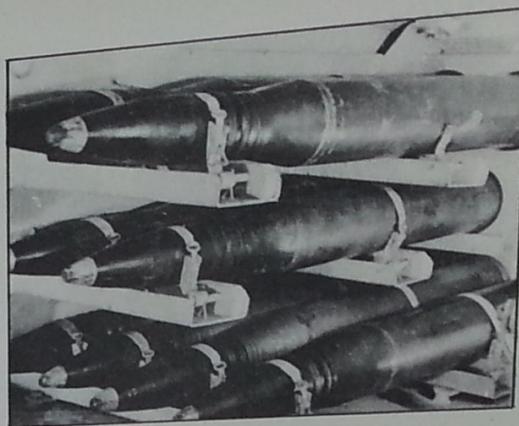
10. GUN LEVELLED - OFF.



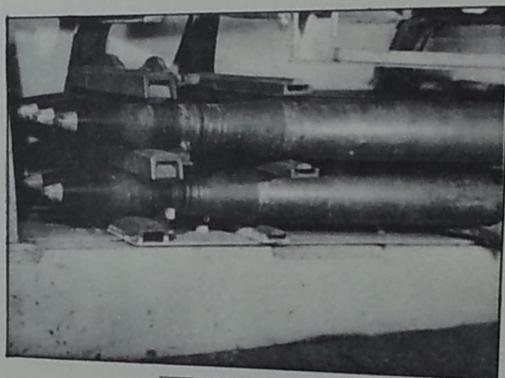
11. GUN ELEVATED.



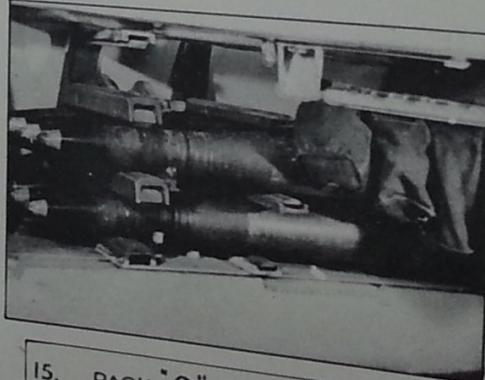
12. GUN DEPRESSED



13. RACK "A".



14. RACK "C"



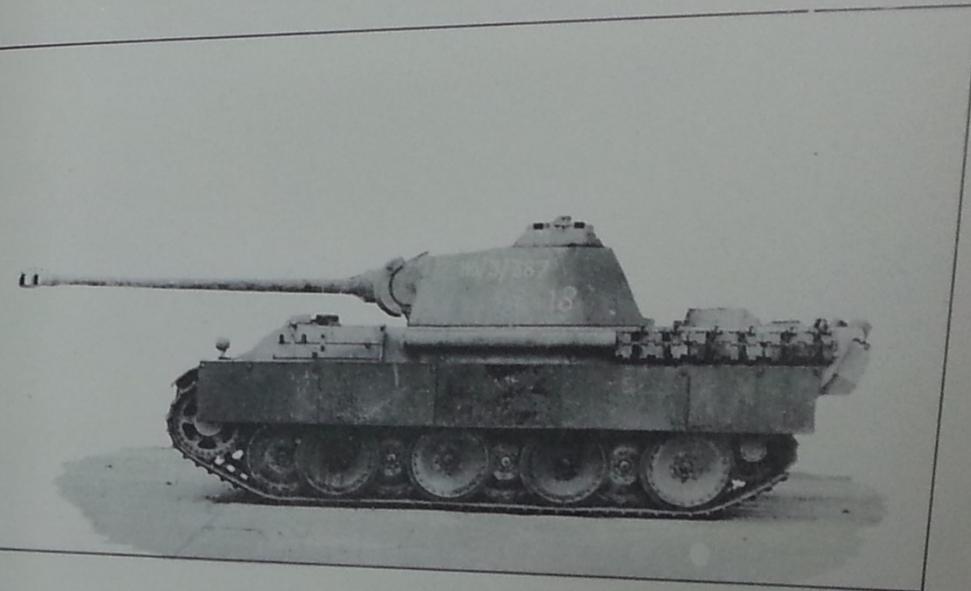
15. RACK "C", SHOWING METHOD
OF STOWING MG 34 BELT
BAGS.

ROYAL TIGER LOADING TRIALS

Bin	Loader	Turret Position	Gun Elevation	Method Used	Round 1	2	3	4	5	6	7	8	9	10	11
4	A	-	Level	Film	11.4	10.6	12.5	10.0	11.2	10.3	10.8	14.5	13.5	14.8	12.9
"	B	-	"	"	9.4	7.6	9.2	9.7	8.1	9.0	8.5	9.2	9.1	10.9	10.1
"	A	-	"	Watch	7.9	7.5	8.5	8.8	8.4	8.0	8.2	8.0	8.9	9.2	9.6
"	B	-	"	"	8.0	8.0	9.8	8.8	8.2	8.3	8.5	9.2	9.7	9.6	9.6
"	A	-	Max. Elev.	Film	7.2	7.8	8.7	8.7	7.7	9.2	7.8	8.0	8.2	9.3	8.1
"	B	-	"	"	7.7	8.1	8.2	8.7	8.0	8.0	7.7	7.9	8.5	8.5	9.0
"	A	-	Max. Dep.	"	9.9	11.9	9.7	11.0	12.2	14.1	8.2	10.2	10.2	12.3	10.4
"	B	-	"	Watch	10.0	10.4	9.9	10.8	8.8	8.6	8.3	10.3	10.0	10.2	9.2
B	A	-	Level	Film	7.7	6.9	7.4	9.0	"	"	"	"	"	"	"
"	B	-	"	"	6.4	7.0	7.1	7.2	7.6	7.3	8.3	8.9	7.8	9.5	9.1
"	A	-	"	Watch	7.3	5.7	7.8	7.5	8.1	9.9	9.7	11.3	8.9	"	Could not reach last two rounds.
"	B	-	"	"	6.1	8.6	7.5	7.3	7.3	7.5	7.7	7.9	7.8	8.9	9.4
"	A	-	Max. Elev.	"	8.2	7.5	7.2	9.0	9.0	7.0	8.0	7.5	8.0	9.5	7.8
"	B	-	"	"	6.4	6.9	7.3	8.8	7.0	7.5	9.7	8.0	9.0	7.9	8.3
"	B	-	Max. Dep.	"	0.0	0.6	0.0	0.9	0.7	11.1	9.0	10.5	9.4	9.5	11.0
C	C	12 o/c	Level	Film	17.2	14.9	21.9	13.7	"	"	"	"	"	"	Drop defl. guard, lead, replace defl. guard.
"	D	12 o/c	"	"	17.9	16.3	20.9	17.9	"	"	"	"	"	"	Centre layer in bin.
															Lowest layer in bin.

SECTION 4.

MOTION STUDY OF THE 'PANTHER'



SECTION 4.

MOTION STUDY OF

PZKPFW V FÜR 7.5 cm KW. K. 42 (L/70) SD.KFZ.171
(THE 'PANTHER')

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5. THE DRIVER
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6. THE BOW-GUNNER
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10. CONCLUSION

PHOTOGRAPHS

APPENDIX

MOTION STUDY OF THE PANTHER

1 DESCRIPTION OF THE VEHICLE

The Fz. Kpfw V ('Panther') is a tank of the heavy cruiser class weighing 45 tons. The length (excluding the gun) is 22' 7", width 10' 10", height 9' 9" and ground clearance 1' 7".

The armament comprises a 7.5cm. Kw K 42 (L/70) mounted coaxially with an MG 34 in the turret, and an MG 34 bow-gun mounted in the hull glacis plate.

The vehicle has a crew of five - commander, gunner and loader in the turret, and driver and bow-gunner in the hull.

The speed of the vehicle is approx. 30 m.p.h. and the radius of action approx. 80 miles.

The vehicle studied was F.V.D.D. No. 3413; it was new and built by British Workshops in the B.A.O.R. A badly-damaged service Panther was also examined.

2 THE COMMANDER

(a) Seat and Positions. The commander's position is in the rear of the turret and on the left side of the main armament. He can either sit on a seat fixed to the turret ring or stand on a small platform raised above the floor.

The padded seat is 9" long and 1' 5" wide and welded to the turret ring at a height of 3' 0" from the floor. When seated, the commander can obtain all-round vision through the seven episcopes in his fixed cupola. Although no backrest is provided, he can lean back against the turret and the position is reasonably comfortable. The seat height should, however, be adjustable to allow for tall and short commanders.

His alternative position is standing on a footrest which is hinged to the empty-round bin and which springs upwards when not in use. The footrest has a roughened surface and is 11" long, 9" wide and 2' 0" high. When standing on the footrest, the commander can observe with his head and shoulders outside the turret. The position is comfortable, but when the vehicle is on the move, the commander's feet are liable to slip off the plate.

(b) Vision. The commander is provided with two vision devices. The first is a set of seven 4"-wide episcopes mounted in the fixed cupola in the roof above his position. An open sight is mounted on the roof in front of the centre eposcope. The episcopes provide all-round vision for the commander when seated; he has therefore no need to expose his head outside the turret. He can turn his head and observe to the rear of the vehicle while remaining seated.

The rubber browpads on the episcopes are very hard and give inadequate protection when the vehicle is on the move.

The commander is also given an "observation of fire" device. This is a scissors periscope, type TSR 1, mounted on a sliding bar on the underside of the turret roof in front of the commander. (see Photos 1 and 2.) The periscope can be moved forwards and backwards and locked in position by a clamp. (As the British Workshops which made the vehicle did not incorporate the clamp, the mounting shown in the photographs is incomplete.) The complete mounting is rigid, and satisfactory to use,

We consider that the combination of the set of episcopes and the scissors periscope gives the commander a reasonable vision range. (c) Conclusion. The commander's seat and footrest are both comfortable, but not fully satisfactory. His vision facilities are reasonable.

3

THE GUNNER

(a) Seat and Position. The gunner's padded seat is mounted forward of the commander's position on the left side of the main armament. (See Photo 3.) It is roughly semi-circular, 1' 2" wide and 1' 0" long and can be adjusted to heights of 1' 4" to 1' 8" in five positions. The seat has a backrest which is curved and padded and measures 1' 1" wide and 3" high.

The seat and backrest are comfortable but not easily accessible, and badly positioned in relation to the gun controls. The latter are described in detail below.

(b) Gun Arrangement. The main armament is a 7.5 cm. Kw K 42 gun mounted high in the turret. The gun prevents movement from one side of the turret to the other.

The gun is semi-automatic, and when the empty cases are ejected, they should hit the deflector shield, and drop through the deflector guard into a bin beneath. The deflector shield is fitted with a spring clip, which should grip the base of the case and ensure that it does not rebound but drops squarely into the bin below. (See Photo 4.)

The bin is on the floor below the deflector guard. (See bottom left-hand corner of Photo 5.) It has two sprung flaps along its length, and these should open downwards when the empty case falls into the bin. They should then close again, thus sealing the bin and preventing any gases left in the case from fouling the turret atmosphere. As a further precaution, a flexible 4" pipe (shown in the right-hand side of Photos 5 and 8) can withdraw gases from the bin through an exhaust fan in the roof.

(c) Gun Controls. The turret can be traversed by hand or power. The hand traverse control is a handwheel 10" in diameter on an almost vertical axis. The 3" handle is on the underside and is too short to be gripped by the whole hand. (See Photos 3 and 6.) Operation of the handwheel requires little effort but is slow, and normally the power traverse would be used for long 'switches'.

The power traverse is hydraulically driven from the propeller shaft through the two-speed gearbox situated below the gun and on the right of the gunner's seat. (See Photo 5.) Speed and direction of traverse are controlled by two footpedals, each 3" by 4", on the floor in front of the gunner. They are shown in Photo 6. When the left or right pedal is depressed, the turret traverses left or right correspondingly. A linkage is fitted to ensure that the pedal plates remain horizontal as they are depressed.

The seat is badly placed in relation to the pedals; the left pedal is in line with the right side of the seat. Consequently the gunner must twist the lower half of his body to the right when he wishes to operate the pedals.

In the vehicles inspected, the pedal-movements were stiff to operate. Considerable foot pressure was required to overcome the inertia and it was very difficult to start and check the traverse smoothly and at the right moment.

A damaged service Panther was also examined and found to be equipped with a different type of footpedals. It will be seen from Photo 7 that each pedal tilts along its transverse axis and the design is basically sounder than that of the pedals described above. No test of the control in operation was possible owing to the vehicle's poor condition.

The elevating handwheel is 10" in diameter and mounted on a transverse axis. It is operated by the gunner's left hand. (See Photo 6.) The handle is $3\frac{1}{2}$ " long and too short to be gripped by the whole hand. In addition, when the gunner is using the control, his hand is liable to chafe against the azimuth indicator. Operation of the handwheel is stiff and therefore slow.

The gun trigger is a steel lever pivoted to the elevating wheel handle. It fires the gun electrically and appears satisfactory.

The gun controls so far described are out of line with the gunner's seat. If the latter had been mounted about 6" further to the right of its present position (and this could have been done without disturbing any turret equipment) the gun could have been controlled with much greater comfort and probably with more speed and accuracy.

An emergency firing device is situated on the floor below the front edge of the gunner's seat. It is a standard German push-button generator type and is protected by a hinged strip steel frame which prevents accidental operation. Although designed to be relatively inaccessible, the control is quite satisfactory to use.

(d) Sighting and Vision. The gun sight, type TZF 12a, is monocular and the front end is articulated to move as the gun is elevated. The eyepiece is stationary and comfortable, but badly positioned, since the right earpiece of the gunner's headset must be pushed to one side before he can look through the sight.

Apart from the gun sight, the gunner has no vision devices.

(e) Conclusion. The gun arrangement in this vehicle is bad; the gun controls are badly positioned relative to the gunner's seat, the power traverse and elevating controls are unsatisfactory to use, and the vision range afforded is inadequate.

The empty-round bin is, on the other hand, well-designed, and probably effective in reducing the quantity of gun fumes in the turret.

4 THE LOADER

(a) Position. The loader's position is on the right of the main armament. No seat was positioned in the vehicle inspected. As the height of the turret is only 5' 3", a loader of normal height cannot stand erect but must stoop. The combination of these factors would cause the loader fatigue, especially if the vehicle were on the move for long periods.

Although the headspace is restricted, the floorspace is reasonable, and allows the loader sufficient room for movement when loading.

(b) Controls. A standard rotating smoke generator discharger is mounted in the turret roof in the loader's position. It does not obstruct the loader. As the latter has no headset in this vehicle, the commander would have great difficulty in ordering him to fire the discharger in the correct direction. The fitting of a multi-barrelled

discharger (the British model), mounted outside the turret and controlled by the commander, would have eliminated this difficulty.

(c) Vision. A 5"-wide episcope is mounted in the turret roof near the coaxial MG 34. It is fixed and gives the loader a field of vision half right of the turret. He can therefore cover an angle which, owing to the position of the cupola, is not covered at short ranges by the commander. The episcope is the sole vision device for the loader, and he has no hatch for 'opened-up' vision.

(d) The loader's position is satisfactory, apart from the absence of a seat.

5

THE DRIVER

(a) Seats and Positions. The driver sits in the front left corner of the hull. There is an upper and lower position, with a separate seat for each. The upper position (see Photo 9) is used when an action is not imminent and the turret is not likely to be traversed. When seated, the driver has his head and shoulders outside the hatch.

The upper seat is positioned by hooking its forward end on to the top of the lower backrest, and the upper backrest onto the hull roof. By adjusting the angle of the lower backrest, the upper seat can be moved forwards and backwards correspondingly. The arrangement is simple and efficient and allows the upper seat and backrest to be completely removed (e.g. when the vehicle is about to go into action). The upper seat is padded, 1' 1" square and 2' 5" above floor level. The padded backrest is curved, $8\frac{1}{2}$ " wide and $2\frac{1}{2}$ " high. The seat and position are comfortable and easily accessible and the large hatch allows the driver considerable body movement.

The lower position is used when the vehicle is closed down and/or the driver is looking through his periscope. (See Photo 10.) The padded seat is 11" wide at the front and 9" at the back, and is 1' 2" long and 1' 4" high. Forward-backward adjustment in five positions is provided. The backrest is padded, 11" wide and 1' 2" high and can be tilted at any desired angle by adjustment of a ratchet and cam operated by a handle on the right side of the seat. The backrest can be dropped back flat to facilitate access to the turret. The long drop from the hatch to the lower seat makes access difficult, and the position is rather cramped.

In both the upper and lower positions, the seats are mounted squarely to the controls, and the driver can travel in reasonable comfort when the vehicle is on the move. Although the seats are satisfactory to use, it takes far too long for the driver to change from the upper to lower position. The type of driver's seat fitted in the American 'Pershing' tank is far more suitable.

(b) Controls. The driver's controls (except for the choke control) are either adapted or duplicated for both the positions. The different positions of the steering levers, gear lever and handbrake are shown in Photos 9 and 10.

In both positions, the steering levers are on each side of the driver's legs. In the upper position, they are 2' 1" long and operated by pulling upwards. As they are very thin, the levers may not stand up to unduly heavy usage. They are easily operated.

The driver adjusts the levers for the lower position by pulling out a plunger, bending the levers about a pivot, and replacing the plunger. In this position, the levers are more rigid and are easily and comfortably operated by pulling towards the driver.

When the engine is running, the steering is hydraulically assisted and quite easy to control. However, when the engine is not running (e.g., when being towed), steering the vehicle requires considerable effort.

The gear lever for the synchromesh gearbox, is pivoted for convenience in both positions. It is mounted on the right of the driver and used for selecting the seven forward and one reverse gears. A latch must be lifted before 1, 6 and 7 gears can be selected, and a second latch before reverse gear can be selected. Although a check may well be essential for reverse gear, the value of the check for 1, 6 and 7 gears seems questionable.

The handbrake is mounted on the left of the driver and has two separate handles, one for each position. Each of these is conveniently placed, but very stiff to operate, and the ratchet, though of simple design, is awkward to engage and release.

The choke control comprises a metal ring on a wire cable connected to the choke linkage, and is situated 2" forward of the right side of the lower seat. The control is easy to operate but difficult to find and can be reached only from the lower seat.

The upper clutch pedal is 2" wide, 5" high and has a convex surface. The bottom of the pedal is 1' 11" above the floor. The pedal is satisfactory to operate and is hinged and sprung for pushing out of the way when the driver is using the lower position.

The lower clutch pedal is mounted on the hull floor and is the same size as the other one. It is easy and comfortable to operate.

The upper and lower footbrake pedals are similar to, but mounted further to the right than, the upper and lower clutch pedals respectively. The pedals are easy and comfortable to operate.

The upper accelerator pedal is shown on the left of the right-hand steering lever in Photo 10. It is 12" wide and 3" high and, unlike the clutch and footbrake pedals, cannot be moved elsewhere when not in use. As a result, when the driver uses the lower position his right leg chafes against the pedal. The upper pedal in this vehicle was rather stiff and tended to cause spasmodic control of acceleration; this can probably be attributed to the new condition of the vehicle.

The lower accelerator pedal is 2" wide and 2½" high and mounted on the hull floor. This pedal also was stiff but otherwise satisfactory.

The two instrument panels are situated on top of the gearbox to the right of the driver. They contain adequate controls and dials but these cannot be seen unless the driver turns his head to the right. However, if the panels were moved elsewhere, although they might be seen more easily from one position, they would be less visible from the other. We therefore consider that their present position is the best compromise.

(c) Vision. When using the upper position, a driver can see to drive with his head and shoulders outside his hatch. The vision range is very good.

When driving 'closed-down' and using the lower position, the driver can see only through a 5"-wide tilting and rotating periscope. His head is adequately protected by a headpad and browpad. He can see the ground from 14' 0" onwards in front of the tank. The single periscope is inadequate, since we consider that the restricted vision would tend to make a driver slow down unnecessarily.

(d) Conclusion. The driver's upper position is comfortable and very convenient for driving, but his lower position is rather cramped and the angle of view through the single periscope is inadequate. The controls are satisfactory.

6

THE BOW-GUNNER

(a) Seat and Position. The bow-gunner's position is in the right front corner of the hull. The seat is padded, 1' 2" wide at the front, 1' 0" at the back, and 1' 2 $\frac{1}{2}$ " long. It is mounted on a steel frame on the floor and is 1' 2" high. The frame is slotted to allow forward-backward adjustment of the seat through 7" in six positions. The back-rest is identical to that in the driver's lower position. Although the seat itself is comfortable, the bow-gunner's knees are cramped between the steering hand housings, which are only 10 $\frac{1}{2}$ " apart. The position is not easily accessible, despite the large hatch provided. Nor is there any provision for 'opened-up' vision.

(b) The Bow-Gun. The bow-gun is a 7.92 mm MG 34 carried in a ball mounting in the glacis plate in front of the bow-gunner. (See Photo 11.) The cranked sight (Type KZF 2) is carried in the same mounting, which also holds the ammunition feed bag and a similar bag for expended cases.

The gun mounting and sight are adequately padded and comfortable, but are positioned about 6" too far over to the left. This is shown in Photos 12, 13 and 14, which show centre, left and right traverse respectively. The bow-gunner would become fatigued when sighting the gun, especially as his knees are already cramped between the steering hand housings.

(c) Vision. In addition to the gun sight, the bow-gunner has a 5" episcope mounted in the hull roof on the right of the bow-gun and facing half-right. It is unpadded and likely to injure the bow-gunner when the vehicle is moving. Had the episcope been mounted facing forward, he could have used it to search for targets for the MG, especially since the MG sight has such a small angle of vision, (18°).

(d) Conclusion. The bow-gunner's position is unsatisfactory; his knees are cramped and he must lean over to the left to handle the bow-gun.

7

LIGHTING

Festoon lamps are fitted

- (a) on the turret roof in front of the commander's cupola,
- (b) on the turret roof above the gunner's position,
- (c) on the turret roof in front of the loader's episcope,
- (d) on the left side of the driver's instrument panels,
- (e) above the right side of the wireless set.

The position of these lamps is quite satisfactory. However, a lamp fitted in the right rear pannier would have assisted loading from Rack A when it was dark inside the tank.

CREW ACCESS

(a) Hatches. The only hatches in the hull front are those for the driver and bow-gunner. These open outwards with spring-assistance. They are 1' 1 $\frac{1}{2}$ " long and 2' 0" wide and, when opened, do not foul the turret on traverse. There is a disadvantage, however, in that when the hatch is opened, the doors drop flat against the hull roof and are therefore awkward to close quickly.

The hatches can be locked from inside or outside the vehicle. The door hinges are a novel feature in A.F.V. design in that they can be disconnected by rotation of a large wingnut in the hull roof above the panniers. Each hatch door can be completely removed from the hull in about 10 secs.

There is only one roof hatch in the turret. This is the commander's fixed 'cupola' in the roof above his position. The cupola is circular, 1' 5" in diameter and 11" deep. The abnormally great depth of the cupola, which has parallel sides, hinders access, but is necessary to house the set of episcopes.

The cupola inspected was modified to take the Puma infra-red night vision equipment.

The cupola door is operated by two handles on the left of the commander's position. It is awkward and slow to unlock and open the cupola. When the door is open it can be swung to the left and locked; in this position, it neither fouls the commander's head nor impedes access to and from the turret. As the hatch door opens sideways and not upwards, the designer's intention was presumably that the hatch would be kept open during an engagement. (If the vehicle were hit, it would take too long for the commander and gunner to get out of it with the door closed.)

Since the main armament and the empty-case bin prevent the loader from moving to the left side of the turret and using the cupola, and since no roof hatch is provided for him, the loader would enter and leave the turret through the rear escape hatch. This is on the right side of the rear plate of the turret and is circular and 1' 6" in diameter. One handle is welded 3" above the hatch inside, and another 8" above the hatch outside, to facilitate access. Owing to the absence of any foot support inside the turret, it is both slow and awkward to enter or leave the turret by the escape hatch.

The hatch can be opened, closed and locked from inside or outside the turret. It would presumably be kept closed but not locked when the vehicle was in action.

(b) 'Baling-Out'. The following table gives the times (in seconds) each crew member took to leave his station and get outside the vehicle as quickly as possible:-

	Cond'r.	Gunner	Loader	Driver	Bow-Gnr.
Hatch open	4	9.5	4.5	3	4.5
Hatch closed and locked	11.5	17.5	11.0	5.5	9

In this trial, all the crew members except the loader used the roof hatches for evacuation. The gunner used the commander's cupola. The loader used the escape hatch.

Although their hatches are identical, the driver 'baled-out' quicker than the bow-gunner because:-

(a) There are very few projections which the bow-gunner can grasp when pulling himself out of the tank.

(b) The position is very spacious.

(c) The seat is so far from the hatch that it is very awkward for the bow-gunner to operate the lock and open the door.

(c) Conclusion. The crew access arrangement is satisfactory.

9 MAIN ARMAMENT LOADING TRIALS

(a) Loading Arrangement. A total of 79 rounds is carried in the vehicle. Of these, 12 rounds are so inaccessible from the turret that they can be considered replenishment rounds only. There is both horizontal and vertical stowage, and none of the eleven racks is inside the turret perimeter. The layout of the ammunition stowage is shown in Fig. I. A full list of loading trials and times will be found in the Appendix.

The following table shows the number of rounds available at various clock traverse positions:-

BEARING (o'clock)	Racks and contents available	TOTAL
12	12 rds. Rack A and 3 rds. Rack E	15
1	12 rds. Rack A and 3 rds. Rack E	15
2	3 rds. Rack E and 1 rd. Rack H	4
3	6 rds. Rack H	6
4	12 rds. Rack D and 6 rds. Rack H	18
5	12 rds. Rack D and 6 rds. Rack H	18
6	12 rds. Rack C and 4 rds. Rack G	16
7	12 rds. Rack C and 4 rds. Rack G	16
8	4 rds. Rack G and 6 rds. Rack F	10
9	6 rds. Rack F	6
10	12 rds. Rack B and 6 rds. Rack F	18
11	12 rds. Rack B and 6 rds. Rack F	18

It will be seen that at 2 o'clock, only 4 rounds are available, and at 3 and 9 o'clock, only 6 rounds are available. These bearings being so near to the 12 o'clock position would be used frequently in action, and should have had more ammunition available. This is a bad feature of the vehicle.

We consider that the amount of ammunition available for the other traverse positions would be adequate for normal engagements.

The loaders taking part in the trials were:-

Loader A - Tpr. Egan, height 5' 4" and

Loader B - L/Cpl. Stidwell, height 5' 5".

FIG 1.

'PANTHER'

PLAN OF AMMUNITION STOWAGE.

See back of Fig 1. Section 2.

(b) Pannier Stowage. Racks A, B, C and D are the four pannier racks which are accessible from the turret. Each rack holds 12 rounds, stowed horizontally. The four rounds in the bottom layer are stowed bases rear, the three rounds in the next layer bases forward, the three rounds in the next layer bases rear, and the top layer of two rounds is stowed bases forward. The arrangement is shown in Photo 15.

Each layer is supported by two steel arms, each of which is hinged and springs upwards when the layer of rounds is removed from it. This facilitates access to the layer below.

Each arm clips to the arm above it by means of the hook-and-eye arrangement shown in Photo 15. The arrangement is bad, since the sprung hook must be lifted upwards to be unlocked. As a result, the sprung upper arm moves upwards as well, and the force required to release the clip is so great that the arm below also moves upwards, complete with the layer of rounds. It therefore requires two hands using a considerable amount of 'brute strength' to unfasten one arm, after which the loader must then unfasten the other. The arrangement could have been greatly improved simply by inverting the clips. One hand would have then been able to undo each clip. The loader could have undone both clips simultaneously, therefore saving time.

(It was noticed when studying the Jagdpanther that the clips were mounted the opposite way round to those in the Panther. It is probable that the Rhine Army Workshops which built the Panther assembled the racks incorrectly, and that the clips should open by a downwards pull. For this reason, and since the clips were taking 10 seconds and longer to unfasten, they were left unfastened during the trials; they probably would be so when the vehicle went into action.)

As the arrangement of the rounds in Rack A, B, C and D is symmetrical, there was need to study only the two racks on one side of the hull, i.e., Racks A and B on the right side. For Racks C and D the comments and loading times will be identical, except for angles of traverse. For instance, loading from Rack A at 1 o'clock is similar in method, and the time taken, to loading from Rack C at 7 o'clock.

The drill for loading from the pannier racks is as follows:-

The loader turns and bends down to the rack; he draws a round clear of the rack, holding the base with his left hand and the neck with his right hand. If the round is stowed base forward, he turns right and, when he faces the breech the round is correctly positioned for loading. If the round is stowed base rear, a different drill must be used. The loader removes the round from the rack, holding the neck of the case with his right hand. Holding the round high, he swings the base from right to left and grasps it with his left hand. The round is now correctly positioned for loading. The end of both drills is identical. The loader inserts the projectile into the breech, rams the round home with his left hand and then operates the safety switch with his right hand.

Rack A. This rack is in the right rear pannier and is one of the two most convenient pannier racks; the other is Rack B. Rounds can normally be loaded from these racks (between 10 and 1 o'clock). Rack A alone can be used at 12 and 1 o'clock. At 12 o'clock, the average loading time per round is 5.8 secs., and at 1 o'clock, 5.5 secs. At maximum elevation, the breech of the gun is very low down and almost touches the empty-round bin. Rounds can be loaded at this position in an average of 6 secs. At maximum depression, although it is difficult to pass a round between the roof and the deflector guard, the round enters the chamber more easily and quickly, and the average loading time is 5.7 secs. per round.

Rounds can therefore be loaded from Rack A fairly quickly but within only a small angle of traverse.

Rack B. This rack is immediately forward of Rack A and can be used for loading at 10 and 11 o'clock. The rack is not as accessible as Rack A and the loading times are correspondingly higher. The average loading time per round at 10 o'clock is 6.7 secs. and 11 o'clock, 7.1 secs.

It will be seen from the loading times for Rack A that the angle of elevation of the gun does not greatly affect the loading time. This applies also to Rack B. This rack is further away from Rack A and loading requires more effort; the loader would therefore use Rack A rather than Rack B whenever possible.

(c) Vertical Stowage. There are four vertical stowage racks accessible to the loader; they are Racks E, F, G and H and contain a total of 19 rounds, all stowed bases down. The racks are similar in design, and are built of sheet metal. Photos 16, 17 and 18 show three of them. The rounds are held by base cups and double top flaps which hinge inwards and which, when closed, hold the rounds rigid. Each pair of flaps is locked by a toggle clip. In the vehicle inspected, the flaps were so badly made that, when the rounds were in position, several of the flaps would not meet and the toggle clips could not be fastened. A further bad feature was that when the flaps were opened and the first round removed, there was no support for the remaining rounds and they were liable to fall over. When this happened, they were not only difficult to find and reach but would also have jammed the turret had it been suddenly traversed. A steel bar placed about 4" from the top of the rack would have prevented this but would also have impeded the removal of the rounds and increased the loading times accordingly.

Rack E. This rack is shown in Photo 16 and contains 3 rounds. The rack is situated in the right rear corner of the hull, and the rounds can be used for loading at 12, 1 and 2 o'clock; the rack is therefore accessible at the principle bearings.

Average loading times are, at 12 o'clock, 6.3 secs.; at 1 o'clock, 5.4 secs.; at 2 o'clock, 6.6 secs.

In common with those for all the other racks, loading times are not greatly affected by the elevation of the gun; at maximum elevation, rounds average 5.8 secs. each to load, and at maximum depression, 6.4 secs. each, with the turret at 1 o'clock each time.

Rack F. This rack is shown in Photo 17 and is situated to the left front of the pannier rack B. As the round is available at 8, 9, 10 and 11 o'clock, it is the best-positioned of all the vertical stowage racks. It contains 6 rounds.

Average loading times per round are, at 9 o'clock, 7 secs.; at 10 o'clock, 6.3 secs.; at 11 o'clock, 6 secs.

Although more accessible than Rack B, Rack F is awkward to reach; this disadvantage is reflected in the loading times, which are higher than those of Rack A.

Rack G. This rack contains 4 rounds and is shown in Photo 18. The rack is situated in the left side of the hull, to the right front of Rack C. As rounds in Rack G are available only at 6, 7 and 8 o'clock, all bearings at which engagements would rarely be fought, no loading trials were conducted using the rack.

Rack H. This rack contains 6 rounds and is situated in the left rear corner of the hull. It is accessible at 3, 4, and 5 o'clock and one round can be removed for loading at 2 o'clock. This single round can be loaded in 6.6 secs.

As engagements at 4 and 5 o'clock would be very rare, loading was studied only at 3 o'clock. At this bearing, the 6 rounds were loaded in an average time of 4.7 secs. per round.

(d) Replenishment Stowage. There are three racks which are not accessible from the turret and which would, therefore, be used for replenishment only.

Rack J is situated in the pannier to the left of the driver, who would, in emergency or when the vehicle was not in action, pass the rounds through to the turret. The rack contains 4 rounds stowed horizontally, base rear, in a single layer.

The two racks K and L each hold 4 rounds and are similar to the other vertical racks, E, F, G and H. The only difference is that a hinged steel plate is mounted on top of the racks to prevent damage by the hull crews' feet. Rack K is situated immediately behind the driver and Rack L behind the bow-gunner, each of whom could pass ammunition from the racks back into the turret.

(e) Conclusion. The layout of the ammunition stowage in the Panther is good. 79 rounds are carried in the vehicle, of which 67 are accessible from the turret; the remaining 12 must be passed back by the hull crew.

The worst stowage feature is the distribution of the rounds; at 2 o'clock only 4 rounds are available, and at 3 and 9 o'clock, only 6 rounds are available. These bearings would be used frequently in action, and should have been more plentifully supplied with ammunition.

Loading times are reasonably fast because the loader has adequate floorspace in which to manoeuvre the rounds, and also because the rounds are convenient to grip and handle. Also the deflector guard rear plate being mounted well back from the breech and the absence of any top rail on the loader's side of the deflector guard allows the loader adequate room to insert the round into the chamber. (See Photo 8.)

CONCLUSION

More consideration for crew comfort would seem to have been given in this vehicle than in any other German equipment studied, though the loader should have been given a removable seat. Vision facilities are good, and convenient for all the crew except the gunner. Loading times are good considering the large ammunition and the relatively small turret. Ammunition availability at certain traverses is outstandingly bad.

We consider the outstanding features of the vehicle to be:-

GOOD FEATURES

Main armament loading times.

Driver's 'opened-up' vision.

Large hull hatches.

BAD FEATURES

No loader's seat.

Position of gunner's and bow-gunner's seats in relation to their controls.

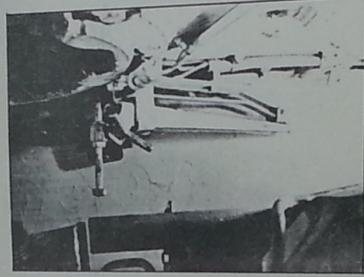
No adjustment for commander's seat.

GOOD FEATURES

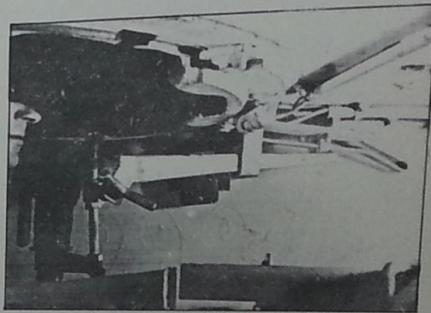
Empty-case bin and fumes
extractor for gun.

BAD FEATURES

Gunner's restricted vision.
Bad controls for power traverse.
Handwheel handles too short.
Small amounts of ammunition
available at 2, 3 and 9 o'clock.
Position of clips on arms in
pannier racks.
Gunner must move headset to sight.



1. SCISSORS PERISCOPE MOUNTING.



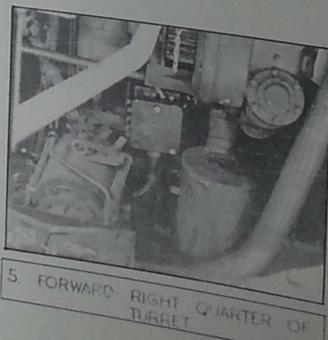
2. SCISSORS PERISCOPE MOUNTED.



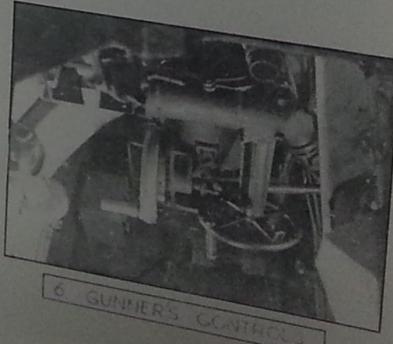
3. GUNNER'S SEAT & CONTROLS.



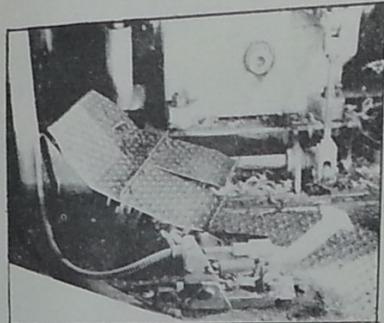
4. SPRUNG RETAINERS ON DEFLECTOR GUARD



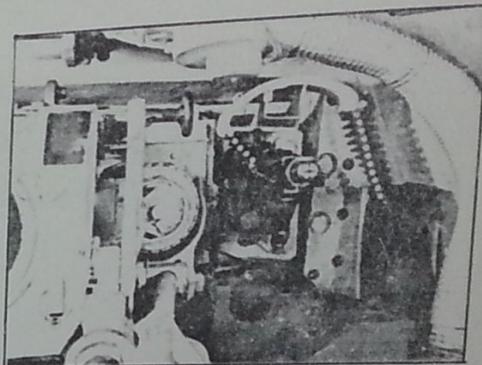
5. FORWARD RIGHT QUARTER OF TURRET



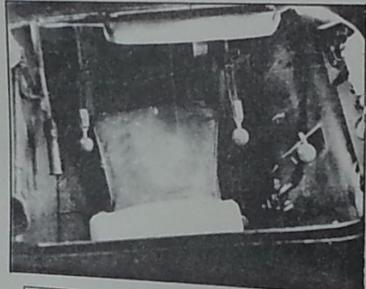
6. GUNNER'S CONTROLS



7. ALTERNATIVE POWER TRAVERSE
FOOT-PEDALS.



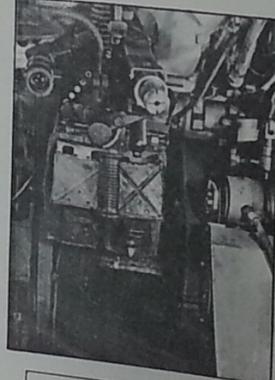
8. COAXIAL M.G. 34 & ROOF FAN.



9. DRIVER'S UPPER POSITION.



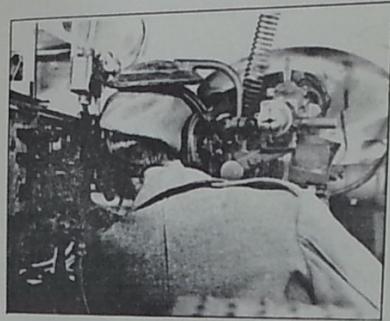
10. DRIVER'S LOWER POSITION.



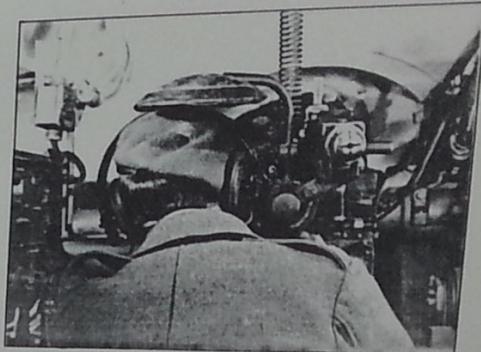
11. HULL M.G. 34.



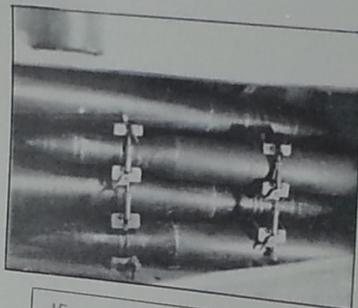
12. HULL M.G. 34 ON CENTRE
TRAVERSE.



13. HULL MG. 34 ON LEFT TRAVERSE.



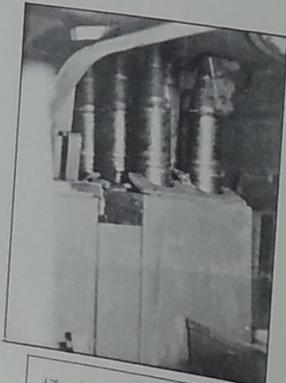
14. HULL MG. 34 ON RIGHT TRAVERSE.



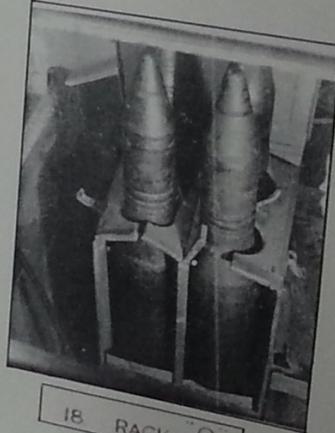
15. RACK "A"



16. RACK "E"



17. RACK "F"



18. RACK "G"

APPENDIX

DETAILS OF LOADING TRIALS AND TIMES

SECTION 5

CONCLUSIONS

COMPARISON OF THE THREE TANKS STUDIED

MOTION STUDIES OF GERMAN TANKS

SECTION 5

CONCLUSIONS

COMPARISON OF THE THREE TANKS STUDIED

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7. LIGHTING
8. CREW ACCESS
 - (a) Hatches
 - (b) 'Baling-Out'
9. MAIN ARMAMENT LOADING TRIALS
10. CONCLUSION.

CONCLUSIONS

COMPARISON OF THE THREE TANKS STUDIED

1 DESCRIPTION OF THE VEHICLES

During the late war, these three tanks which were the largest turreted vehicles produced in quantity by the Germans, were unique also for the fact that they carried such heavy armament. The following Table compares the significant features of the German tanks with those of Allied design which were used during the same period:-

VEHICLE	WEIGHT	LENGTH	WIDTH	HEIGHT	ARMAMENT	CREW	TYPE
TIGER	56 tons	20' 8 $\frac{1}{2}$ " excluding gun	12' 3"	9' 5"	8.8cm Kw. K.36 (L/56) *	Five	Heavy
ROYAL TIGER	70 tons	23' 10" excluding gun	12' 0"	10' 2"	8.8cm Kw K.43 (L/71) *	Five	Heavy
PANTHER	45 tons	22' 7" excluding gun	10' 10"	9' 9"	7.5cm Kw K.42 (L/70) *	Five	Heavy Cruiser
CHURCHILL IV.	39 tons	24' 5" overall	10' 8"	8' 2"	7.5cm or 6 pdr.	Five	Infantry
CHURCHILL VII.	40 tons	25' 2" overall	10' 8" with louvres	8' 2"	7.5 cm	Five	Infantry
CROMWELL	28 tons	21' 1" overall	10' 0"	7' 9"	7.5cm or 6 pdr.	Five	Cruiser
CHALLENGER	33 tons	26' 4" overall	9' 7"	8' 9"	17 pdr.	Five	Heavy Cruiser
COMET	33 tons	21' 6" excluding gun	10' 0"	8' 9"	7.7cm.	Five	Heavy Cruiser
SHERMAN IV.	30 tons	20' 1" overall	8' 9"	9' 3 $\frac{3}{4}$ "	7.5cm	Five	Cruiser

* (L-) denotes the length of the gun in calibres.

Below are given the dimensions of British post-war tanks:-

VEHICLE	WEIGHT	LENGTH	WIDTH	HEIGHT	ARMAMENT	CREW	TYPE
CENTURION I and II	44 tons	25' 1" excluding gun	11' 0"	9' 3"	17 pdr.	Four	Heavy Cruiser
X BLACK PRINCE	50 tons	26' 3" overall	11' 9" with spare track	9' 0"	17 pdr.	Five	Heavy
CENTURION III.	49½ tons	25' 1" excluding gun	11' 0"	9' 3"	20 pdr.	Four	Heavy Cruiser

X Not an operational vehicle.

2 THE COMMANDER

(a) Seat and Position. In each vehicle, the commander's position is in the left rear quarter of the turret and a seat is provided.

Alternative positions are provided so that the commander can see with his head either inside or outside the turret. The Tiger has an upper and a lower seat; the Royal Tiger has a seat and a pair of footrests; and the Panther has a seat. In all three vehicles, the commander can stand on the turntable.

None of the seats is adjustable; although forward-backward adjustment is not essential if the seat is well-positioned, allowance should be made in A.F.V.s for height adjustment. A backrest is provided only in the Royal Tiger. Although the commander of the Panther can lean back against the turret wall in reasonable comfort, in the Tiger he must lean back against his respirator. Some form of padded backrest is essential for a tank commander; his seat should also be designed so that he is not liable to slip off it when the vehicle is on the move over rough country.

(b) Controls. In the Tiger, the commander has a handwheel which allows him to traverse the turret and lay the gun approximately on a target which the gunner cannot see. In the other two tanks, the gunner must rely on the commander's instructions.

Although we consider that some form of control by which the commander can traverse the turret is highly desirable, we do not think that a handwheel, such as that installed in the Tiger, is completely satisfactory. The commander cannot turn his wheel unless the gunner holds the latch on the main handwheel, and when the commander operates his wheel, the gunner's hand may be flung off his wheel and the turret locked again. In addition, the commander's control is very awkward, slow and inconvenient to operate.

The spade grip provided for the commander in recent Allied tanks is more suitable, since it is easy and quick to use and does not occupy much space in the position. The commander should, if possible, have a very spacious position, so that he can handle maps and apparatus quickly and comfortably.

(c) Vision. In all of the tanks, the commander can have his head and shoulders outside his hatch when the vehicle is not in action. This allows him to guide the driver over difficult terrain and through confined spaces.

All three tanks have fixed cupolas with either episcopes (Panther and Royal Tiger) or glass blocks (Tiger) mounted in them. Complete all-round vision is not, however, afforded. Several "blind areas" are covered by other episcopes in the vehicle, and this policy should be adhered to under such conditions. Wherever possible, a rotating cupola should be fitted, with either glass blocks or episcopes contained in it, and spaced so that the commander can scan any angle without having to rotate the cupola excessively.

An adjustable mounting is incorporated in the tanks to hold a scissors telescope. This instrument is fitted primarily for observation of fire. The S.T.T. report on Tiger states that the telescope gives the commander "an excellent means of aligning the gun onto a target the gunner cannot see."

The existing instrument is removable. When fitted, it restricts access to the turret since it projects through the cupola. Although not bulky, it is inconveniently situated and the mounting appears crudely designed. The telescope has the undoubted advantage, however, of allowing the commander to observe fall of shot accurately without exposing his head outside the turret.

The vision arrangement for the commander of these tanks is reasonable but not fully adequate. The commander should have all-round vision (with no "blind spots") and he should be able to see the ground near to the tank, in case of short-range attacks by 'bazookas' etc.

3

THE GUNNER

(a) Seat and Position. In all three tanks the gunner sits in front of the commander, on the left side of the main armament. His seat is padded, and has a back-rest. The design of all the seats and backrests is satisfactory, and they are all comfortable. But in each tank, the gunner's position is an outstandingly bad feature. The gun controls are badly positioned and/or badly designed. The gunner has the most cramped position in most A.F.V.s, but this is to be expected because he is surrounded by gun controls and mechanisms and because usually the commander is stationed behind him. However, if these controls are well-designed and conveniently placed, the gunner can sit in comparative comfort. The apparent lack of consideration for these features in not only these three but all German A.F.V.s inspected must have resulted in fatigue and discomfort for the gunners together with the danger of inefficiency of fire control.

(b) Gun Controls. In all three tanks the turret can be traversed either by hand or by power. Two of the traverse handwheels are 10" in diameter; that in the Tiger is 9" in diameter. The handle on the Tiger and Panther is 3" long, and is difficult to be gripped by the whole of the gunner's hand. It should be about 4½" long. The handwheel in the Royal Tiger is adjustable, but even in the best position, it is still awkward to use. Moreover the axle is vertical and badly positioned between the gunner's knees. The handwheel in the Tiger and Panther is not adjustable. In the former, the wheel is mounted on a vertical axis, while in the latter, the wheel is mounted on a transverse horizontal axis. The wheel in the Tiger is the most comfortable to use. In

all three vehicles, the hand traverse wheel is operated by the gunner's left hand.

Whereas in British tanks the power traverse is controlled by a spade-grip, the Germans used tilting footpedals. While the latter have the advantage of not hindering the gunner's body, and also freeing the hands for other work, they have the following disadvantages:-

- (i) The footpedals in each tank are badly positioned relative to the gunner's seat, and are therefore very awkward to operate.
- (ii) The linkages from the pedals to the power traverse gearbox are elaborate, and would need regular lubrication; lack of maintenance may make operation of the control stiff, and therefore inaccurate.
- (iii) The controls are likely to be inadvertently operated.
- (iv) The footpedals are exposed to damage and mud.
- (v) The gunner can take his feet off the pedals yet the turret still continues to rotate.
- (vi) The footpedal mechanisms are incapable of "fine" switches.

We recommend that the easier and more accurate hand control of power traverse in British Tanks be continued. A spade-grip control is more desirable than a handwheel (as used in the American Westinghouse system) since the latter must be constantly rotated and is wasteful of effort. In addition, when the gunner turns a handwheel, his head is liable to move from side to side and therefore affect his sighting.

Gun elevation in the three tanks is controlled by the orthodox type of handwheel. In the Tiger and Royal Tiger, the wheel axis is horizontal, and the handle is mounted on the left side of wheel. In the Panther, the handwheel axis is almost vertical, with the handle on the underside of the wheel.

In both the Tiger and Royal Tiger, the handwheels are too low down for comfortable operation, and they are not easily accessible. In all three tanks, the wheel handles are too short to allow adequate purchase.

The guns in all three tanks are fired electrically. In the Tiger and Royal Tiger, the firing control is a curved steel bar hinged behind the elevating wheel. Unless the wheel handle is at the top of its arc of movement, the gunner must remove his hand from it to reach the firing control. This is not serious, however, since the gunner might well finish laying by gripping the rim of the wheel at the top for fine adjustment. His hand would then be adjacent to the firing control.

The control in Panther is a short, curved latch which is hinged onto the elevating wheel handle. There is a danger of this control being accidentally operated as the gunner grips the handle when elevating the gun. A further disadvantage is that, to avoid the danger just mentioned, the gunner may hold the handle with the firing latch away from his hand; in this position, the latch will not be easily accessible at the crucial moment when the gun is 'on target'.

We do not consider that either type of German control is completely satisfactory, and recommend that, if the power traverse is controlled by a spade grip, the firing control should be mounted inside the spade grip towards the top, where it can easily be operated by the gunner's first finger. Since a well-designed spade grip needs little pressure to operate, there will be little danger of the gun being fired accidentally.

The gun should, if possible, be fired electrically, either by solenoid with percussion primers or by electrically-actuated primers. The latter arrangement is preferred, since rounds containing electric primers are less liable to be accidentally exploded when roughly handled, and such rounds do not necessarily need primer protection (primer clips) if the bases are exposed when stowed.

Bowden-type mechanical firing mechanisms are less desirable since they are generally stiffer, less positive and require more maintenance than electric mechanisms.

In addition to the main firing control, the Germans fit an emergency control, which is used in the event of an electrical breakdown in the vehicle circuit. The control consists of a press-button magneto, which is self-generative and independent of the tank batteries. The magneto is mounted on the turret floor, and is either mounted where it cannot easily be reached, or is protected by a hinged steel strip, to prevent the gun being fired accidentally.

(c) Sighting. The gun sight in Royal Tiger and Panther is articulated at the front end, and the eyepiece is clamped to the roof and remains stationary when the gun is elevated. The Tiger sight is rigid and the eyepiece goes up and down with the gun.

Only in the Panther is the eyepiece adequately protected. In the Tiger and Royal Tiger, the rubber browpad is too hard for comfort, and that in the Tiger is badly-shaped, since it tends to knock the gunner's headset off when he is sighting.

The ideal browpad should be well-shaped and on an adjustable mounting, so that it will give adequate protection to any shape of head, especially when the vehicle is on the move. The gunner should be able to get his eye to the sighting eyepiece without fear of striking his nose or brow on any hard objects. The browpad should be large enough to enable the gunner to look squarely through the eyepiece as soon as his head touches, and yet should be small enough to permit him to wear a headset comfortably when sighting. Above all, the browpad should be thick, soft and comfortable, and porous enough to be still soft and comfortable when fully compressed. It should also, if possible, be replaceable and easily washable.

In the Panther and Royal Tiger, no vision device other than the gun sight is provided for the gunner. Unless the gun sight has an exceptionally wide angle of vision, we consider that it is inadequate and that the gunner should have a further instrument which will enable him to scan a wider field of view than that of the gun sight.

4 THE LOADER

(a) Seat and Position. The loader's station in all three of these vehicles is on the right side of the turret.

The two larger tanks have seats provided for the loader, and, although the two models of Panther that were inspected had no seat, we understand that a loader's seat was fitted in the later models of that vehicle.

Clearly a loader's seat is desirable because:-

(a) If the vehicle is small, the loader will be confined in a very small space and will probably be unable to stand erect.

(b) If the vehicle is large, the ammunition carried will probably also be large, and consequently tiring to load; the rounds will also have to be carried greater distances from stowage to gun.

We therefore recommend that a loader's seat be included in future specifications. (The seat should be removable to allow the loader adequate space to handle the ammunition; alternately, the seat should be designed to collapse or swing clear when not in use. A padded backrest is also desirable, since the loader is liable to be thrown about violently when the vehicle is on the move.)

The loader's position in both the Tiger and Panther is remarkably clear and spacious. The fitting of an auxiliary traverse handwheel in the Royal Tiger restricts the loader's access to the forward panniers, and his headspace is marred by the spring which assists the opening of his hatch. The latter feature could easily have been overcome by redesigning the spring and mounting it outside the turret.

(b) Vision. The vision devices provided for the loaders of the three tanks are all designed or mounted differently. In Royal Tiger, he has a 5"-wide episcope mounted above the coaxial M.G. and facing forward. In the Panther, a similar episcope is mounted on the right of the M.G. and faces half-right. The loader in the Tiger has a vision slit with glass block mounted in the turret wall at 2 o'clock. The slit faces half-right and covers an angle not covered by the commander's devices.

Normally a tank would go into action with the gun loaded and the loader standing-by until a target is sighted. If possible, therefore, he should be given one or more devices, adequate to enable him to search for targets, either independently, or covering an angle which is "blind" to the commander. If searching independently, he should be given a rotating periscope on a wide-angle episcope. If covering an angle for the commander, he should be given an episcope centred on that angle but also embracing as wide an angle as possible on each side of that angle.

5

THE DRIVER

(a) Seat and Position. The driver in all three tanks sits in the front left corner of the hull. In the Tiger, he has only one position, but in the two other vehicles, his seat is adjustable to an upper position (opened-up) or a lower position (closed-down). The Panther actually has two separate seats, one clipping on top of the other, while the seat in the Royal Tiger has a generous height adjustment.

It is a great asset for a driver to have two positions. The lower one is obviously essential, since it enables the driver to see to drive without exposing himself. The upper position is desirable when the tank is out of action, since when using it the driver can see over a much wider angle and, generally, closer to the tank. This enables him to drive with greater confidence; to rely less upon the commander's instructions; to drive the tank over rough and/or narrow ground; and it reduces the driver's tendency to slow down unnecessarily. In addition, it gives the driver an opportunity to move from the normally cramped lower position to a less fatiguing one and it enables him to judge "the lie of the land" more accurately.

The design of the seat is important, since the occasion will arise when the driver wants to change positions quickly. The double seat in the Panther is unsatisfactory for this reason. We consider that the

driver's seat in the American "Pershing" tank is well designed, and might well be copied. The "up-down" control should be readily accessible, yet so positioned that it will not be tripped by the driver's foot as he lowers himself through his hatch. The seat should be padded to counteract the rough travelling the crew have in the hull front, and the backrest should also be well-padded, and adequate to hold the driver on his seat without safety-straps. The driver's controls and his hatch should be designed to be adaptable to both positions.

(b) Driving Controls. The controls in the Panther and Royal Tiger are either adapted or duplicated to allow the driver to reach them from either position. The clutch, footbrake and accelerator pedals are arranged from left to right respectively. The Germans prefer flat plates for pedals rather than the 'stirrups' used in many British vehicles.

We favour the German practice because:-

- (a) A "stirrup" is operated only by a small part of the foot.
- (b) The foot is more liable to slip forward on a "stirrup" than on a pedal.
- (c) It is a smoother and more comfortable action to pivot the foot round the ankle than it is to push the foot forward.
- (d) The foot must be completely withdrawn from a stirrup before it can be replaced on another. This is time-wasting and tedious.

However, if the control has a large arc of travel, the stirrup probably would be more desirable, since, on a footpedal, the foot would have to tilt through a large angle. This would tire the driver, and might even be impossible if his boots and/or anklets were tight.

The footpedals fitted in all three tanks were satisfactory.

The gearbox in both the Tiger and Royal Tiger is preselective. The driver operates neither his clutch pedal nor his accelerator pedal when changing gear; both these operations are performed automatically by the gearbox, whether the gear is changed "up" or "down". The clutch pedal is used solely for engaging a gear before the tank moves off.

The gearbox in the Panther is synchromesh and has seven forward and one reverse gear.

Obviously, any type of gearbox which calls for less driver effort than others is desirable, but not at the expense of mechanical unreliability or increased maintenance needs.

The Germans employed (for emergency use) the standard manual steering, controlled by two levers, one on each side of the driver's body. In the Panther, these levers also controlled the hydraulic steering system. However, in the Tiger and Royal Tiger, the hydraulic steering arrangement was controlled by a semi-circular wheel, mounted on an adjustable telescopic column. The wheel in the Royal Tiger was also adjustable for height, and could therefore be used in comfort from either the upper or lower position.

The steering wheel was tested and found to be very satisfactory. It was easily accessible, comfortable to use, and would steer the tank in either direction when only one hand was holding it.

Unfortunately, the steering wheel controlled only the hydraulic steering system. This is ineffective when the engine is not running (e.g., if the tank is being towed) and a pair of orthodox steering levers

is therefore fitted for manual steering. This is undesirable, since it means duplication of controls in an already cramped compartment.

Research should be carried out on wheel control of steering, especially on adjustable wheels which can be used when the driver is in any position.

Orthodox ratchet handbrakes are fitted in each tank on the left side of the driver. These are stiff to operate and require two hands. That they are mounted near to the driver's left hand is therefore immaterial.

The ratchet locking the footbrake is regarded as less satisfactory than the handbrake arrangement because:-

(a) The ratchet is normally not easily accessible.

(b) It is liable to be accidentally operated.

(c) The ratchets fitted on some German vehicles were prone to jamming.

On the whole, the driving controls in all three tanks are reasonably satisfactory. They are mounted squarely in relation to the seat and the are easy and convenient to handle.

(c) Vision. The driver's vision facilities when driving "closed-down" are inadequate in all three tanks. In the Tiger, he looks through a visor, which is protected by a laminated glass block, while in the Panther and Royal Tiger, a single tilting and rotating periscope is provided.

The vision range when using these devices is very limited. The driver would probably slow down unnecessarily when he saw a possible hazard and he would also have to rely on the commander's instructions when negotiating particularly difficult ground. This is undesirable, since the commander should be concentrating on his own duties.

At least two 5"-wide tilting and rotating periscopes are necessary to enable a driver to see comfortably and effectively from a "closed-down" tank. The periscopes should be thickly padded to prevent injury to the driver over rough country.

No provision for driving "opened-up" is made in the Tiger. In the two other vehicles, the driver can have his head and shoulders outside his hatch and see to drive in comfort. His arc of sight is excellent, an essential feature when driving such large vehicles.

6 THE BOW-GUNNER

(a) Seat and Position. The bow-gunner in all three tanks sits in the front right corner of the hull. He is given a comfortable seat and backrest, and though his position is otherwise spacious, his footroom is cramped because his feet are hemmed in by the steering band housings.

The ratchet-and-cam arrangement, by which the angle of the backrest is adjusted, is simple and apparently quite effective. The backrest can be dropped back flat in the Tiger and Royal Tiger; this facilitates access to the turret and is therefore a noteworthy feature.

(b) Bow-Gun. The bow-gun employed is a 7.92 mm. MG 34 which, in all three vehicles, is controlled by a pistol grip and headpan. The gun is breech-heavy and therefore a compensating spring is incorporated in the

mounting. In the Tiger, despite the spring, the gun is still unbalanced and the gunner must press upwards against the headpan to counteract it. This soon becomes both tiring and painful, and is a very bad feature of the mounting.

The padding on the gun mounting is adequate.

In the Panther, the bow-gun is mounted about 6" too far over to the left. The gunner must therefore lean over to the left to sight and fire the gun. This is uncomfortable and tiring; when the vehicle is on the move, these faults are magnified, and the bow-gunner has difficulty in keeping his balance on the seat. Apparently, little thought was given to user comfort when the position was designed. The only satisfactory method of having the bow-gunner seated squarely to the gun is to move the ball mounting further right, since the seat cannot be replaced elsewhere.

(c) Wireless Set. The wireless set in all three tanks is situated either to the right or left of the bow-gunner, where it can be quickly and easily reached in comfort.

(d) Vision. The standard German episcopic telescope, type K.Z.F.2, is mounted in all three tanks. It is well-padded and appears satisfactory.

In addition to the sight, a 5" fixed episcopic is mounted in the hull roof and faces half-right. It is unpadded.

An episcopic mounted facing forward would have been more advantageous, since the bow-gunner could have used it to look for targets over a wide angle and without needing to handle the bow-gun.

7 LIGHTING

The interior lighting in all three vehicles is adequate, since a light is mounted in each crew member's station.

We recommend, however, that a light be fitted near the 'ready' bins in tanks to enable rounds to be easily located for loading when it is dark inside the turret.

8 CREW ACCESS

(a) Hatches. The driver's and bow-gunner's hatches are identical in each tank, except that they open in opposite directions.

In the Panther and the Tiger, the hatches open upwards with spring-assistance and then fall outwards on a hinge. They are therefore awkward to re-close, and a crew member must expose himself to pull the doors upwards. The doors in the Panther drop flat and therefore do not foul the turret on traverse. Those in the Tiger do not drop flat and neither arrangement is satisfactory.

The hatch doors in the Royal Tiger are not hinged, but pivoted. When closed, they lie flush with the hull roof. To open them, the crew member pushes up the pivot, then twists the door around it until it locks. He can open and close the door without exposing himself outside the vehicle, and the doors do not foul the turret on traverse. This seems to be the ideal design of hatch door.

Although periscopes cannot be fitted into this type of door, they can be fitted on the hull roof instead. There they are less liable to be damaged, and can be used when the driver is in his lower position and the hatch is open.

In all three tanks, the gunner has no hatch and must use the commander's cupola for evacuation. This is very undesirable, because the gunner's position is usually the least accessible in the tank.

The commander's fixed cupola is circular in all three vehicles, and contains his vision devices. For this reason, it is deep and therefore restricts evacuation. In addition, the fixed cupolas have "blind spots"; a rotating cupola has not and is therefore advocated.

The cupola door in the Tiger is hinged and opens upwards with spring assistance. When open, the door does not fall back flat but rests almost perpendicularly and therefore increases the "silhouette height" of the tank. We do not consider it suitable.

The cupola door in the other two tanks is pivoted, like the hull doors in Royal Tiger. It is opened, closed and locked by a complicated linkage which is time-wasting and unsuitable. When equipped with a quicker method of opening, these doors would be completely satisfactory.

The loader has a roof hatch in the Tiger and Royal Tiger. The hatch is rectangular and hinged at the front. The door opens upwards with spring assistance, and falls forward flat. It does not therefore increase the height of the tank, but is difficult and dangerous to close, since the loader must expose himself to reach the front end of the door.

When closed, the door fittings in the Tiger project inside the roof and restrict the loader's headroom. The same happens if the door in the Royal Tiger is open or closed.

A loader's hatch is obviously very desirable, especially when the gun and other fittings prevent the loader from reaching the commander's cupola. A roof hatch, whose door pivots sideways to open, is, in our opinion, most suitable. No roof hatch is provided for the loader in the Panther. Instead, he is given an escape hatch which is circular and fitted in the turret rear plate. It can be opened, closed and locked from inside or outside the turret, and would presumably be kept closed but unlocked when the tank was in action. Owing to the absence of adequate foot support inside the turret, it is both slow and awkward to leave the turret by the escape hatch, and a roof hatch would have been more suitable.

Emergency escape hatches are fitted in the Tiger and Royal Tiger. In the former tank, the hatch is mounted in the turret wall at 4 o'clock. It is difficult to open and cannot be closed from inside the turret without considerable assistance from outside. Furthermore the hatch door falls on the hull roof when open, and fouls the turret on traverse.

The escape hatch in the Royal Tiger is mounted in the back plate of the turret bulge. The hatch is rectangular and partly masked by the ammunition in the bulge bins. Even when the bins are empty, only a thin man can use the hatch effectively. The hatch cannot be closed easily from inside the turret and fouls the latter on traverse.

We consider that neither of these escape hatches is satisfactory for crew evacuation. They would be useful, however, for restowing the turret with ammunition, since the crew need not lift the rounds over the turret to pass them through the roof hatches.

A small circular hatch is fitted in the roof of the Royal Tiger turret; this is used for disposal of the empty cases after firing. The cases in the Panther and Tiger would be disposed of probably by ejection through the commander's cupola.

(b) 'Baling-Out'. In 'baling-out' from each tank, the gunner took longest. Then came the commander, loader and bow-gunner. The driver

took least time of all because his hatch was large, easy to open, and he had adequate support for his feet. Both he and the bow-gunner had a shorter distance to move through than the turret crew, but the bow-gunner's position was spacious and he had little foot support and few projections to grasp when pulling himself out.

9 MAIN ARMAMENT LOADING TRIALS

The stowage of ammunition, and the time taken to load it into the gun, is of considerable interest.

The method of stowage differs in all three vehicles. In the Panther, no ammunition is carried in the turret; it is all stowed either horizontally, base rear in the panniers, or vertically in small racks on the hull floor beyond the turret perimenter.

Ammunition for the 8.8 cm gun in the Tiger is stowed horizontally in the panniers, and also horizontally in the underfloor bins.

Only in the Royal Tiger, which carries the ammunition in the large bulge in the rear of the turret, is a large quantity of ammunition available at all traverse positions. The position of these 'ready' rounds is always immediately behind the gun, where it is most easily accessible. The rounds are completely exposed and carried above the level of the turret ring.

The following table gives full details of the stowage:-

	PANTHER	TIGER	ROYAL TIGER
Total No. of rounds carried.	79	92	64 or 70
No. of rounds in armoured bins.	None	None	None
No. of rounds in sheet metal bins.	None	70	None
No. of rounds stowed underfloor.	None	22	None
No. of rounds stowed without any protection.	79	None	48
No. of rounds accessible at <u>all</u> turret bearings.	None	None	16 or 22
No. of rounds which are accessible from the turret at certain bearings. (excluding underfloor stowage.)	67	64	52 or 58
No. of rounds in the 'best' bins available at 12 o'clock.	15	32	16 or 22
Average loading time of these rounds, in seconds.	5.9	Not known	8.8
Total numbers of rounds accessible at various clock traverse positions.	0' clock		
	12	15	46
	1	15	20
	2	4	36
	3	6	20
	4	18	20
	5	18	20
	6	16	40
	7	16	40
	8	16	20
	9	10	32
	10	6	20
	11	18	20
		18	40
			27 or 33
			34 or 40
			34 or 40
			27 or 33
			34 or 40
			27 or 33
			23 or 29
			30 or 36
			23 or 29
			34 or 40

It will be seen that no ammunition in these tanks is protected from shell splinters, and that in the Panther the rounds are completely exposed.

Although it is a wise precaution to protect those rounds which are not normally used for loading between 10 and 2 o'clock bearings, we consider that the 'ready' rounds in an A.F.V. should not be carried in a fully-armoured bin. Our reasons are:-

- (a) Rounds in the "ready" bins must be easily accessible. The loader would probably open the bin doors as soon as loading was anticipated. Thus the rounds are no longer fully protected.
- (b) The armoured "ready" bin often slows down loading, and almost always hinders the loader, who is prone to injure his hands on the bin sides when removing the round from the confined space inside the bin.
- (c) The bin armour occupies valuable space, which could be used for stowing additional rounds, or the extra weight of armoured 'ready' bins could be used to reinforce the vehicle's armour.

(It should be recorded that British designs are already approaching the "ideal" design in their layouts and arrangements for F.V. 201.)

None of the three German tanks studied is ideal from the loading aspect. The Panther has too few rounds accessible at the important bearings of 2, 3 and 9 o'clock; the pannier bins in the Tiger are unsatisfactory and make loading difficult; and the empty case must be disposed of before another round can be loaded in the Royal Tiger.

10 CONCLUSION

The following features are common to all three tanks:-

GOOD FEATURES

- Spacious position for loader.
- Design of seats and backrests.
- Driving arrangement.
- Commanders' alternative positions.
- Large number of rounds stowed in vehicles.

BAD FEATURES

- Crew's seats badly placed in relation to their controls.
- Design of ammunition bin and fittings.
- Gunner and bow-gunner should have periscope to assist sighting.
- Gun controls badly designed and positioned.
- Gunner's cramped position.

Little consideration has been given, in the design of these vehicles, for the comfort of the gunner. Furthermore, most of the crew's controls are so positioned as to be operated only with discomfort and the resultant fatigue. A short study of each vehicle's mockup by a competent physiologist would have revealed most of these undesirable qualities.

We consider that the gunner and bow-gunner should have adequate vision facilities; in all three tanks this is not possible with the equipment provided.

The ammunition bin fittings are badly designed in all three tanks; hence loading times are higher than need be, and the loaders are more prone to injury than they would be when loading from well-planned stowage.

Though the basic design of these tanks is generally sound on the aspects studied, more consideration for, and detailed study of, user comfort would have ensured that their crews fought in comfort, and with less expenditure of effort.

Nenius Whittemore

Lt. Col.,
C i/c Motion Study Wing,
M.O.R.U.

Distribution List.

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SA/AC	1
D.M.T.	2
M.C. of S	1
D.W.D.	1
D.R.A.C.	2
R.A.C. School	1
S.A.E.	1
D.R.A.	1
D.M.E.	1
War Office Library	2
Admiralty Motion Study Unit	2
T.P.A. 3 (a)	1
D.G.F.V.	6
P.D.T.D. (D)	1
Ordnance Board	1
Defence Research Liason (Canada)	6
Australian Army Staff	4
N.Z. Military H.Q.	2
Mil'y Adviser, Union of S.A.	3
Military Attaché' U.S. Embassy	2
B.A.S. Washington	6